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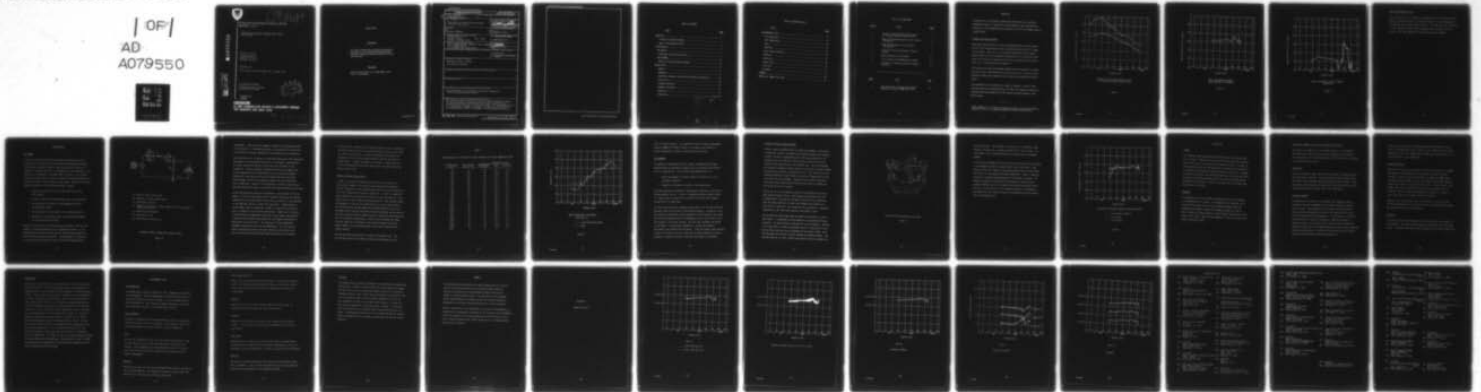
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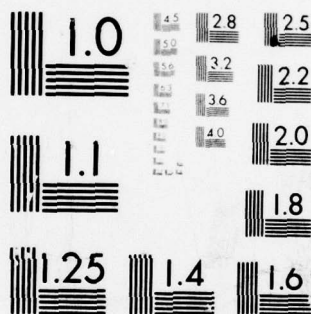
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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
CORADCOM-78-0176-F

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DEVELOPMENT OF IMPROVED EARPHONE-EARCUP SYSTEM
FOR AVC HELMET

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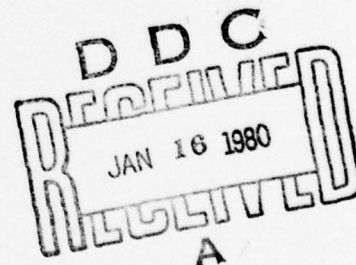
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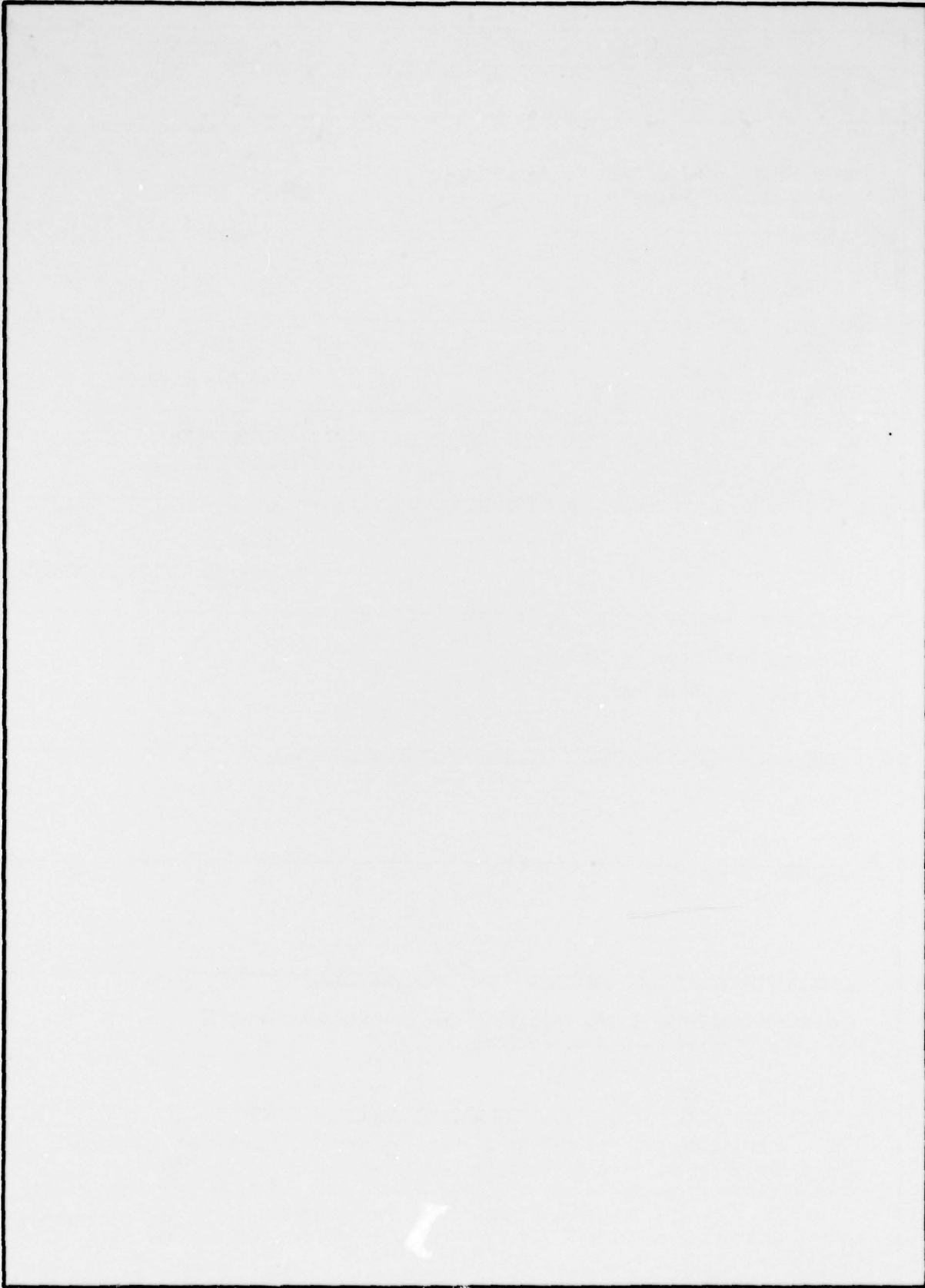
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OBJECTIVE

The objective of the technical effort described herein was a two-fold development project to improve the noise-attenuating and intelligibility properties of the earphone-earcup system used in the DH-132 Armored Vehicle Crewman Helmet.

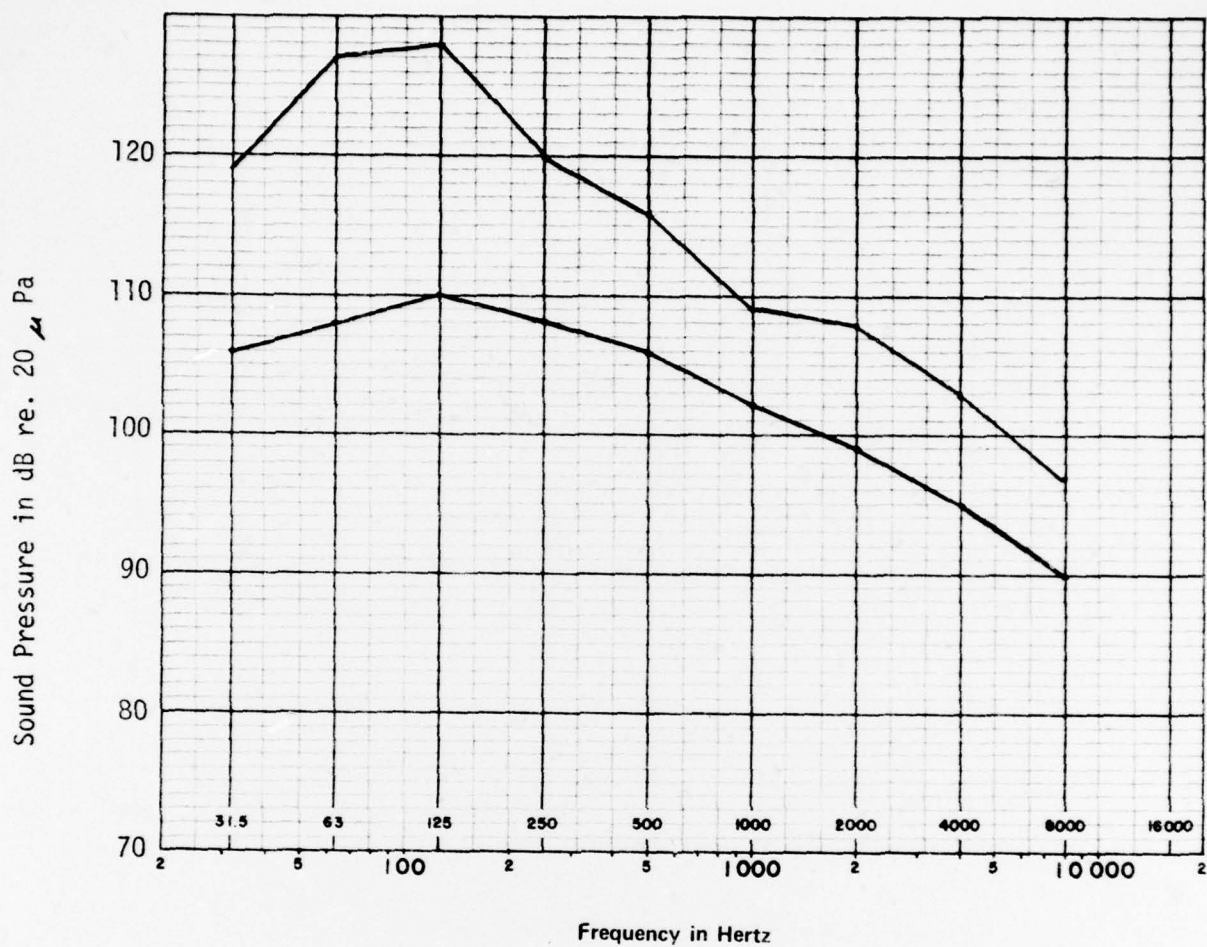
Problems with DH-132 Helmet

High sound pressure levels of noise are generated within tracked armored vehicles which necessitates the use of hearing protection for all crewman in the vehicle. When used in the prototype Mechanized Infantry Combat Vehicle (MICV) the noise attenuation characteristics of the DH-132 Helmet permit only one hour of exposure to the noise to comply with the requirements of U.S. Army publication TB MED 251.¹

The Electro-Voice Model 993 earphone element which was designed to operate against the ear, approximately a 6cc cavity volume, has a very non-linear frequency response when operated in the large cavity volume of the DH-132 earcup.

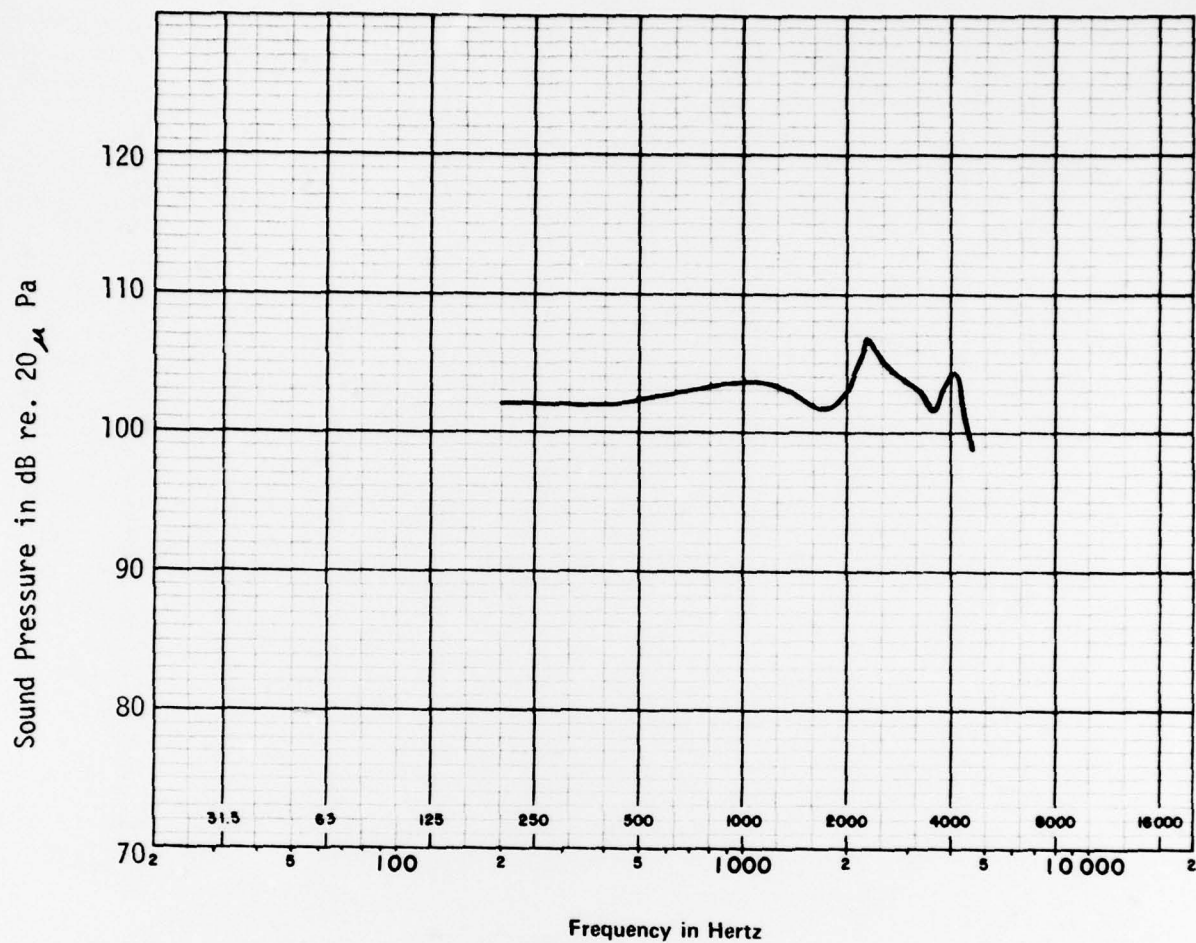
The seriousness of these problems is shown in Figures 1, 2, and 3 which show the sound levels generated within the MICV, and frequency response of the Model 993 when operated into a 6cc coupler and when operated in the DH-132 earcup.

¹USAARL REPORT NO. 77-8, Medical Assessment of Acoustic Protective Devices Proposed for Use in a Prototype Mechanized Infantry Combat Vehicle.



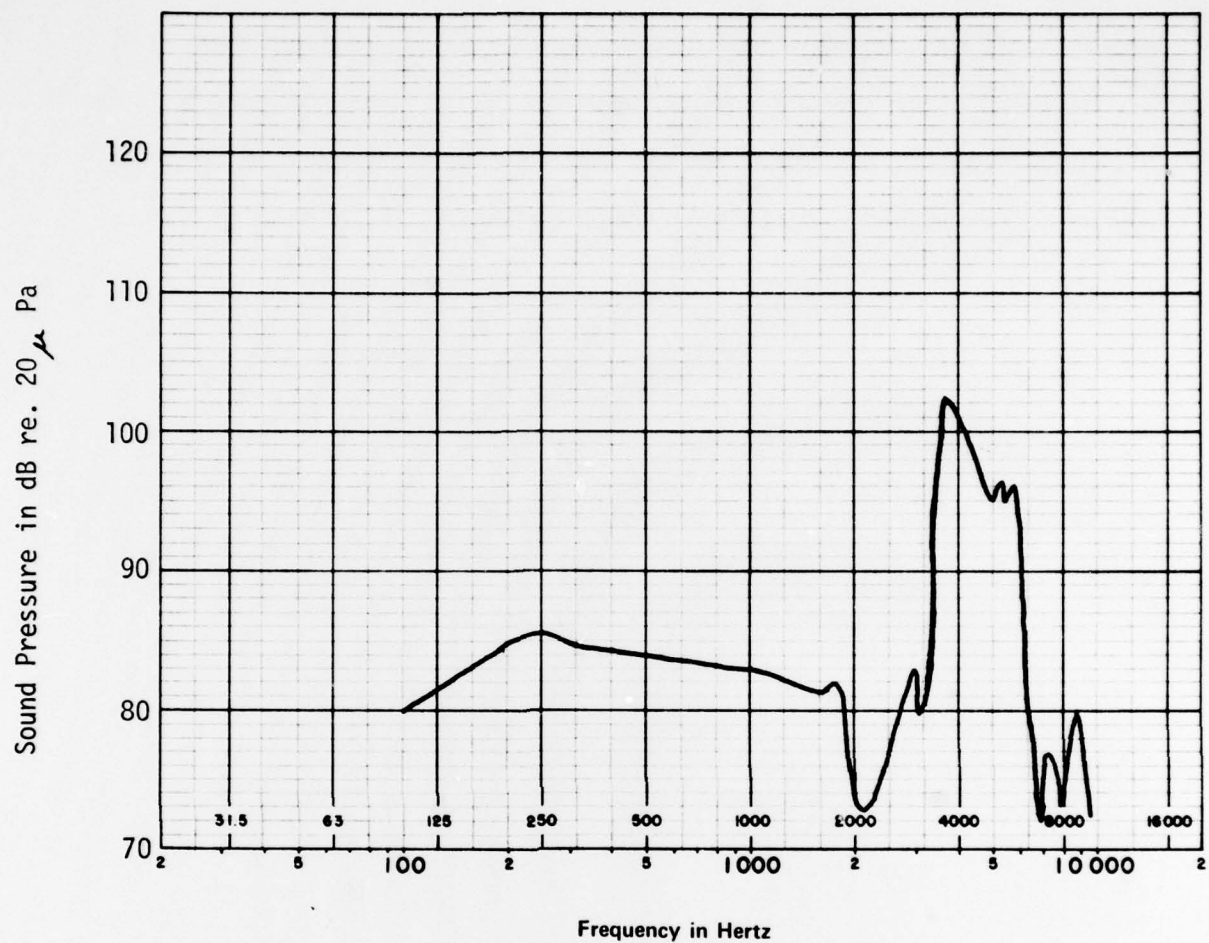
ENVELOPE OF NOISE SOUND PRESSURE LEVELS
FOR PROTOTYPE COMBAT TRACKED VEHICLE

Figure 1



MODEL 993 EARPHONE RESPONSE
ON 6cc COUPLER, 1 mW APPLIED

Figure 2



MODEL 993 EARPHONE IN DH-132 EARCUP,
1 mW APPLIED

Figure 3

Goals of Development Effort

One of the goals of this effort was to improve the noise attenuation of the earcup to allow eight hours of continuous exposure to noise encountered in the MICV and other tracked armored vehicles. The other goal was to generate a linear frequency response from the earphone when operated in the new earcup. This report demonstrates how these goals were attained.

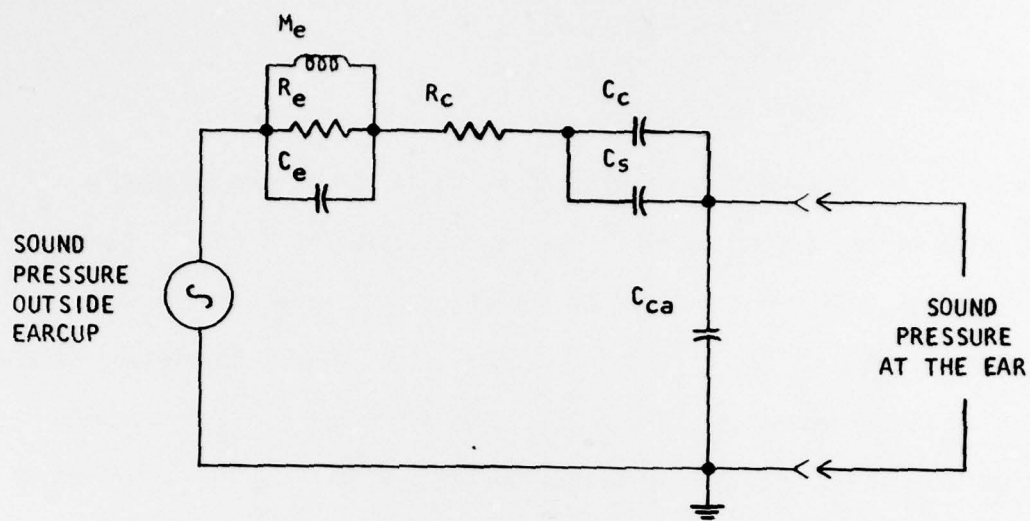
SYSTEM DESIGN

THE EARCUP

In order to understand the noise-attenuation of the earcup we used a simulation of the system to find areas where improvement could be made. An electrical equivalent circuit of the earcup was used along with a computer to evaluate the effects of changing the various parameters of the earcup on its attenuation. The model shown in Figure 4 is an improved version of a model used on a previous contract which has been modified to include the effects of the stiffness of the earcup. Changes to the earcup system are subject to the following conditions, however:

1. Weight of the earcup shall not be more than the existing DH-132 earcup.
2. A means to retain the earphone element shall be incorporated.
3. The earcup shall be physically interchangeable with the existing DH-132 earcup.
4. The earcup shall be constructed of an insulating material.
5. Earcups shall use the same switch and boom mounting hardware as the existing DH-132 earcups.

Analysis of the noise of the MICV shows that attenuation of the low frequencies is the most important area of improvement required. It was determined that the earcup volume could be increased approximately 25% and still meet the above restrictions. The improvement in attenuation by the larger earcup volume fell short of the DS-AF-0265A(A) design



M_e = Mass of total earcup system

R_e = Damping of earcup plastic material

C_e = Compliance of earcup

R_c = Damping of earcushion (Ignores damping of skin as earcushion value is much larger)

C_c = Compliance of earcushion

C_s = Compliance of skin

C_{ca} = Compliance of earcup cavity

ELECTRICAL CIRCUIT SIMULATION OF EARCUP SYSTEM

Figure (4)

requirements. Working with the computer simulation and experimenting with various materials, it was determined that a new earcushion filler material could provide the greatest improvement in low frequency noise attenuation.

Examining the circuit in Figure 4, we see that reducing the series compliance represented by the earcushion and the skin on the wearer's head decreases the signal presented to the ear via the cavity of the earcup at low frequencies. Using the computer simulation and tests on our dummy head, we have determined that the compliance of the skin limits the maximum attenuation of the earcup, with mass and volume fixed by restrictions above, between 30 and 35 dB, assuming a perfect seal and an earcushion with no compliance. Because of the differences in wearer's heads and comfort when wearing the helmet, an earcushion with some compliance must be used.

To meet the earcushion compliance requirements a new earcushion filler was needed. We tried a foam material called "Low-Perm" foam which has improved characteristics over the present filler; yet, this material is only produced in one compliance and has a closed cell construction. Another material called "Temper Foam" was found that is made in an open cell construction which is produced in five different compliances. Temper Foam is sensitive to both pressure and temperature along with a slow recovery rate property. A compliance that provides good comfort and low frequency attenuation is obtainable with this material. The compliance is highly temperature dependent, becoming very stiff at low temperatures. In actual use the wearer would warm the cushion with their hands and, when placed on the head, the warmth from the body would keep the cushion soft for comfort.

We are not able to obtain all the minimum attenuation values required by the specification, even with the increased volume and new cushion filler (see Table I and Figure 5). We feel the attenuation obtained at low frequencies is close to the highest practical value for this type of earcup design. A stiffer earcushion is available in Temper Foam, yet it will be uncomfortable and would require excess pressure against the head to obtain a seal.

Additional Earcup Design Details

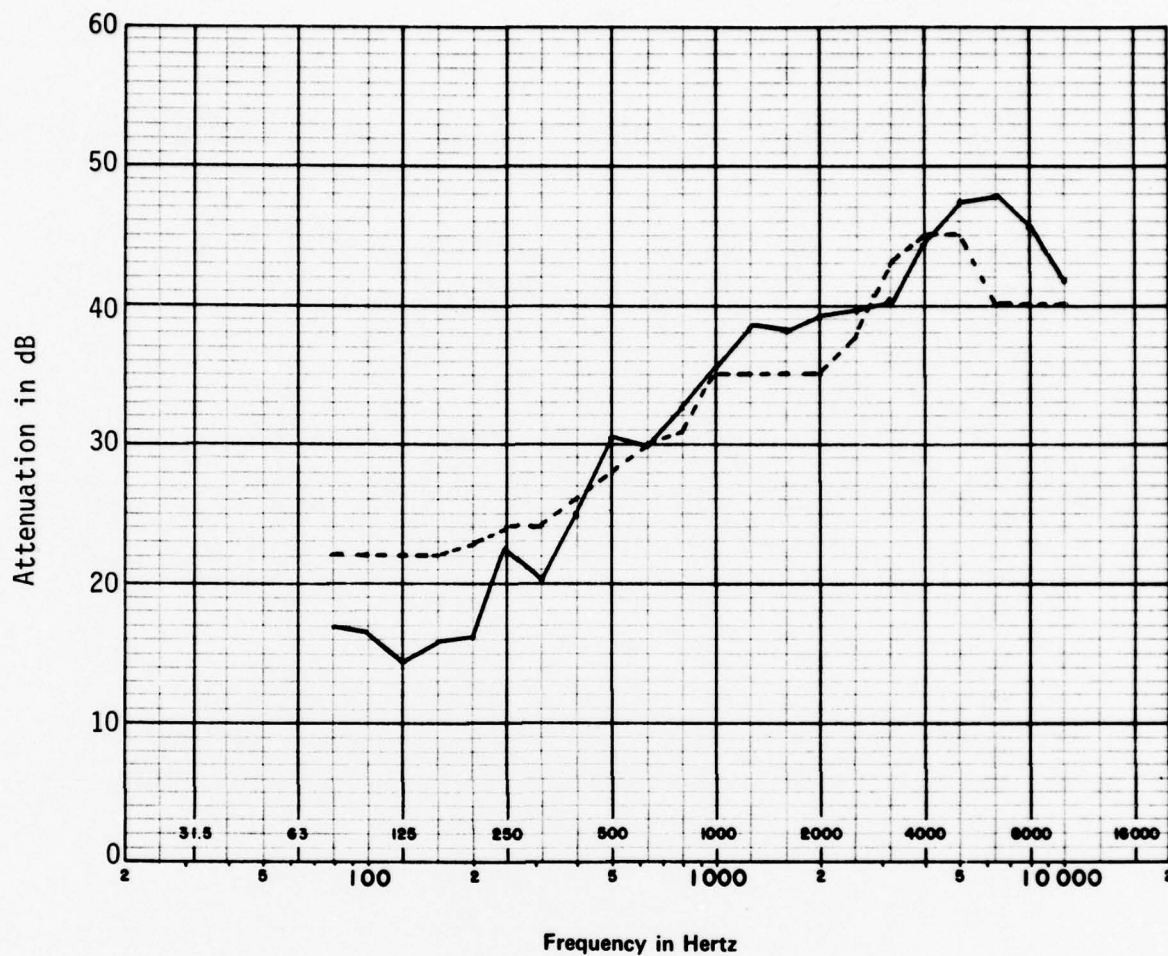
In order to increase the volume and keep the mass of the earcup the same, requires changes in the design of the earcup shape and material. The wall thickness had to be decreased which makes the earcup construction less stiff, reducing high frequency attenuation. In order to reduce the weight additionally and retain the stiffness of the thick ABS wall in the thinner wall, we used a nylon foam plastic material. When properly foamed and assembled, a nylon and nylon-foam earcup will be the same weight as the existing design and more rugged than the ABS design now used. Our prototypes used an ABS and nylon-foam construction because we would have to make four injection molds to produce the parts, where only two of the parts are of a new design configuration. Weight of the prototypes was higher than that which will be realized in the production models of the new design; however, the performance should be the same or better for the lighter versions.

For the earcushion cover we used a polyether polyurethane film. This film has been found to have superior properties when compared to the

TABLE I

Mean Attenuation of Twenty (20) Helmets Produced on Contract DAAB07-78-C-0176

1/3 Octave Band in Hertz	SPL of Noise Used for Test	Attenuation in dB		
		Specification (Minimum)	Mean	Deviation
80	93	22	16.9	3.3
100	102	22	16.4	3.6
125	107	22	14.5	3.8
160	105	22	15.7	3.6
200	102	23	16.1	3.7
250	108	24	22.4	2.8
315	108	24	20.3	1.8
400	105	26	24.8	2.0
500	103	28	30.4	2.3
630	101	30	29.9	3.3
800	99	31	32.7	2.4
1000	99	34	35.4	1.5
1250	99	34	38.4	1.8
1600	98	34	38.0	2.7
2000	98	34	39.1	2.0
2500	95	38	39.6	2.3
3150	95	43	40.3	5.5
4000	91	45	44.2	2.1
5000	90	45	47.5	2.6
6300	88	40	47.8	3.6
8000	86	40	45.8	2.6
10000	79	40	41.9	1.8



MEAN ATTENUATION OF 20 HELMETS
(SEE TABLE I)

----- Specification (Minimum)
——— Mean

Figure 5

vinyl film used presently. We tested this film on a previous development contract (DAAB07-76-C-0149) in which it was shown to be flexible at sub-zero temperatures, fungus resistant and tear resistant.

THE EARPHONE

As explained in the beginning of this report, the Model 993 and other earphones which are designed to operate into a 6cc cavity do not perform well in a large earcup. Two possible design modifications are:

1. Mount the earphone to closely couple it to the ear as it was designed to operate.
2. Redesign the earphone to operate in the large earcup.

From past experience we decided to concentrate our efforts on placing the earphone against the ear. To make a lightweight earphone element operate in a large earcup, we would have to sacrifice efficiency and frequency response which is undesirable.

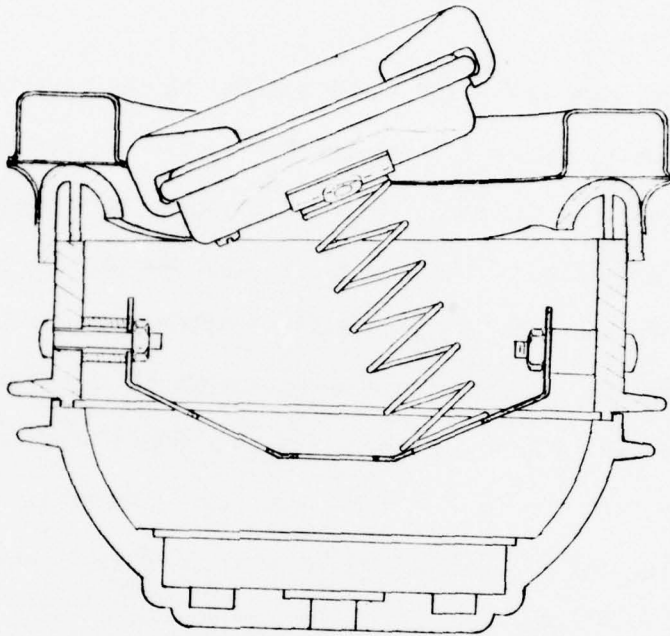
Positioning and sealing the earphone against the ear are the most difficult problems caused by the closely coupled design approach. Variations in user ear dimensions necessitate a loose attachment of the earphone to the earcup. The positioning mechanism must be lightweight, exert a small force to hold the earphone in the proper position, and allow easy placement and removal of the helmet. An additional requirement is to make the earphone a replaceable item separate from the earcup. Since the earphone cover presents a hard, flat surface to the ear, some form of cushion between the ear and earphone is required to provide a good seal and comfort to the wearer.

Design of Closely Coupled Assembly

Figure 6 shows the method chosen to support the earphone in the earcup. A compression spring is attached to the earphone element and a mounting bracket. We chose to permanently attach the spring assembly to the earphone as this provided the lightest weight construction and only required minor modifications to the earphone case. For the prototypes the spring was soldered to metal brackets at each end--an assembly method that would not be used on a production version. The reliability of the soldered connection has been found to be poor even though the unit used in the drop test held together. Production units should incorporate some sort of metal tabs from the brackets which could be crimped over the spring and lock it in place.

A force of $1/3$ to $1/2$ kilogram was chosen to be applied by the spring when pressing against the ear. Most earcups are designed with a one kilogram force. If we used one kilogram of force for this application, then the earcup would have to apply two kilograms force against the head, which is excessive! The spring force was selected as a reasonable compromise for the total force applied to the wearer's head.

Various materials and earpad shapes for sealing the earphone to the ear were tested. A lightweight ring fashioned out of polyurethane foam was evaluated. The foam provided a good seal but has two drawbacks. Because of its compliance it allows the earphone to move in relationship to the head and thus lowers the noise attenuation of the earcup system. Also, the foam would be difficult to clean, presenting a hygiene problem. The selected material is a soft, rubber-like plastic that can be molded into

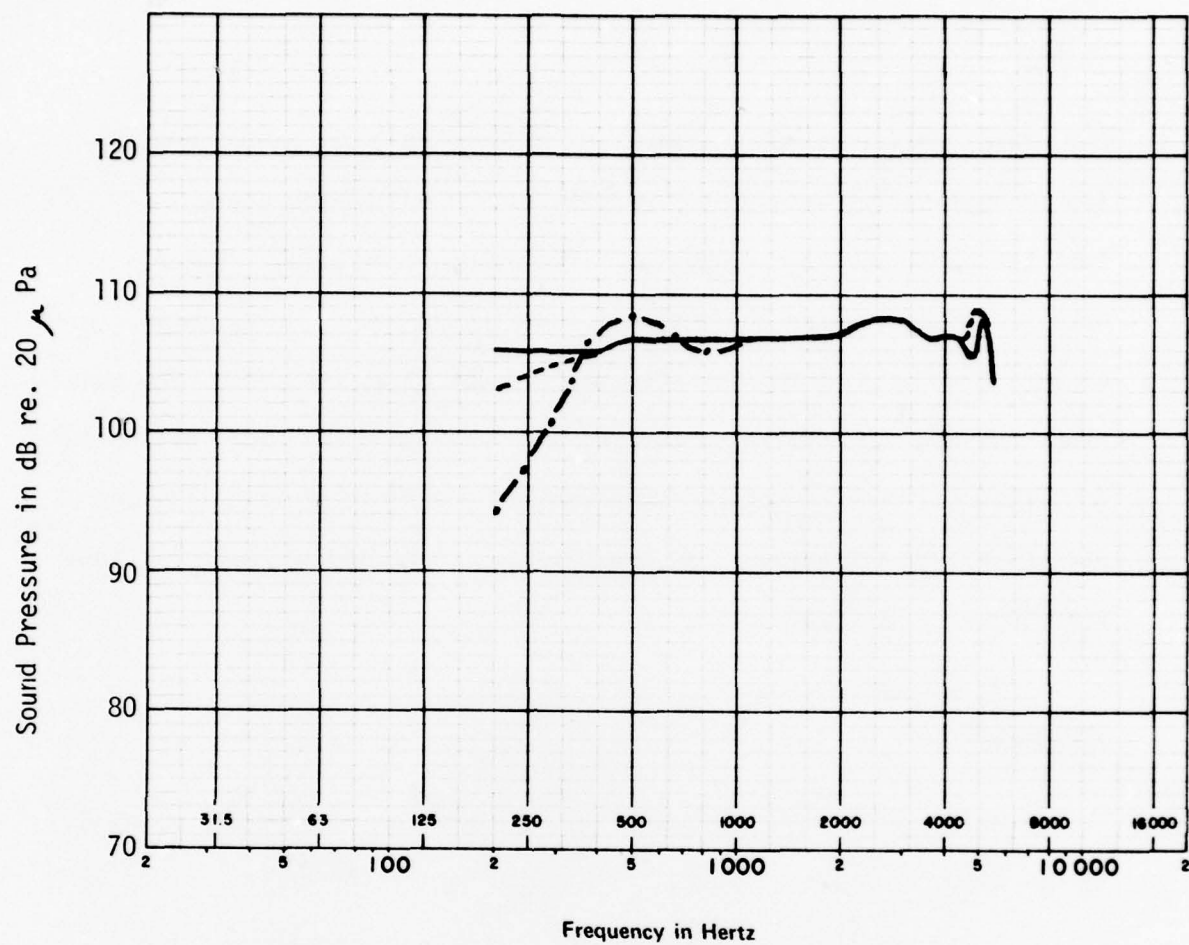


Cross Section of Earphone-Earcup System

Figure 6

the desired shape. This material, "Satinflex", has a compliance almost identical to human skin, is fungus resistant and is easy to clean. We have molded it as a replaceable earpad to be placed over the earphone element.

Since we had to compromise the force applied to the ear, the seal obtained is not adequate to obtain a response that is flat to 200 Hertz. When properly fitted, the frequency response measured at the ear consistently falls within a 6 dB envelope from 400 to 5000 Hertz. Figure 7 shows the variation in response obtained because of differences in sealing. The frequency response is better than we would expect to obtain from an earphone modified to work in the earcup and should provide good intelligibility. We feel the loss in low frequency response is acceptable as the added force for a good seal would be uncomfortable when the helmet is worn for extended periods.



VARIATIONS IN RESPONSE CAUSED BY CLAMPING PRESSURE

- 6cc Frequency Response
- 1 Kg Force
- .-.-.- 1/3 Kg Force

Figure 7

DESIGN TESTS

Weight

Our prototypes weigh approximately 25 grams more than the earcups they are to replace. Examining the density of the nylon foam parts, we found that the parts were not processed by the vendor correctly. In order to make good parts, water cooling would have to be added to the tooling and an injection molding machine with better control is required. The added delay and cost to modify the tooling and make new parts would only result in parts with reduced weight and have little affect on evaluating the performance of the earcup. We chose to go ahead and use the nylon foam plastic parts as received.

Impedance

The impedance of all the earphones was measured with the units mounted to the dummy head test fixture. The impedance of the earphones was 10 to 15 ohms lower than the value of the impedance measured when the earphones are unloaded. Because the impedance changes less than 2% from a loaded to unloaded condition, the measurement technique has little effect on the result. Measuring the impedance in free air is easier and yields the desired results.

Dielectric Strength, Insulation Resistance and Overload

These tests are common to all our earphone designs. We use materials and construction techniques that allow our earphones to consistently pass these tests. All the earphones made on this contract were subjected to and passed the above tests.

Sensitivity

With one milliwatt of power applied to the earphone, the output pressure was always above 104 dB SPL. The specification allowed a minimum level of 85 dB SPL for an earphone which would operate into the earcup. Since the closely coupled approach has been used, 104 dB SPL should be the new minimum level for one milliwatt input in this application.

Frequency Response

As explained in the section on the earphone, the frequency response measured at the ear is dependent on the pressure applied to provide a seal to the ear. When measured on a 6cc coupler or with sufficient pressure applied and measured at the ear, the response falls within a 6 dB envelope between 200 and 5000 Hertz. The high mass of a practical 1000 ohm voice coil limits the response to a 5000 Hertz maximum. It might be possible to use smaller wire in the voice coil to extend the response to 6000 Hertz as the specification calls for, but past experience shows the resulting unit is difficult to build, would be less reliable, and might have difficulty passing an overload test.

Because of the variations in microphone placement and human ear dimensions, we recommend that the 6cc coupler be the standard for testing the earphone with the limits between 200 and 5000 Hertz rather than the in ear technique which is not standardized.

Harmonic Distortion

Measuring the distortion per the design specification presented a problem. Our earphones, when operated into a 6cc coupler and against the ear 'typically', have less than 1% distortion. We placed the dummy head in our large anechoic chamber, which is the quietest room we have, where the ambient noise level is on the order of 45 dB SPL. The noise level in the chamber looks like 1% harmonic distortion at the measurement level of 85 dB SPL. Only the 105 dB SPL measurement level gave us a signal to noise level sufficient to measure harmonic distortion.

Because of the low distortion levels and expense of testing, only the 105 dB SPL measurement level should be used as a specification requirement for harmonic distortion of the earphone.

Linearity

A constant voltage versus frequency at three voltage levels was applied to the earphones. The output sound pressure was recorded for the three input levels. The output sound level varied linearly with the input voltage level.

Attenuation

Various ways of measuring the noise attenuation of the earcup system were used for evaluation. The values obtained in Table I were measured on a dummy head with a noise spectrum that simulated that of a tracked armored vehicle. These values are not as good as expected, but are representative of those to be realized in actual usage. When a flat sound spectrum at lower sound pressure levels is used instead of the shaped spectrum, the values of attenuation are greater and correlate better with our computer simulation. We do not report the latter attenuation values as they apply to a test method which is not representative of actual use. Tests were made with a miniature microphone placed in a subject's ear to further verify the attenuation values of the dummy head test fixture. Because of electrical signal to noise, the attenuation at high frequencies could not be measured accurately. This is because the sensitivity of the miniature microphone is much lower than the one inch B & K microphone used in the dummy head. The values in the low to middle frequencies agreed with that recorded with the dummy head. More theoretical study is needed to determine why the attenuation at high sound levels decreases when compared to moderately high sound levels.

ENVIRONMENTAL TESTS

Low Temperature

An earphone-earcup system was exposed to -50° C temperature as specified in DS-AF-0265A(A). After the temperature of the unit had stabilized, a signal was applied and the level recorded. At the low temperature the level increased 2 dB. When returned to ambient temperature, the level and response were identical to that taken before the test.

High Temperature

No change in performance of the earphone-earcup system was experienced as a result of exposure to 160° F temperature. When checked at 160° F the level had decreased one dB from the level at ambient temperature.

Rain

The rain test trapped more water in the front cover than expected. Only a slight shake was used to remove the water before testing the unit's response. Minor degradation was noted immediately after the rain test. Later, when the rest of the water trapped had been removed, the unit showed no degradation.

Immersion

Immersion tests were run twice on the earphone-earcup system as required by the design specification. We recorded the frequency response before and after the test, and only minor differences were noted.

Dust, Fungus and Blast

These tests were not performed on this contract. The design and materials used in the earphone and earcup have been shown to be resistant to these tests, thus, we passed over these tests to concentrate on other tasks in the design.

Humidity

Examination of the unit after exposure showed no visible change. No degradation of the sensitivity was noted after the test.

Vibration

Exposure to the vibration test caused a minor change to the frequency response. The unit still met specification requirements as a result of the exposure.

Shock, Drop

Dropping a unit 26 times on to a two inch thick piece of plywood backed by concrete from a height of four feet caused no degradation to the unit's performance, even after immersing it in water as specified by DS-AF-0265A(A)

Salt Fog

One unit was exposed to the 48 hour salt fog test of MIL-STD-810C, Method 509.1, Procedure I. Only a slight discoloration on the spring assembly was observed with no degradation in the frequency response.

Altitude

The earphone-earcup system was subjected to an operating and non-operating altitude test. Because of the air tight seal of the earcup to the dummy head test fixture, the unit would not equalize rapidly at a 15,000 feet simulated altitude. When a small leak was provided in the earcushion seal, the unit equalized normally and the response changed only 3 dB at the high frequencies relative to the ground level response. In actual use this sealing characteristic should not present a problem. If data from the field shows this to be a problem, then an equalization port can be added. A non-operating altitude test of a simulated 40,000 feet altitude caused no degradation to the frequency response when the unit was tested afterward.

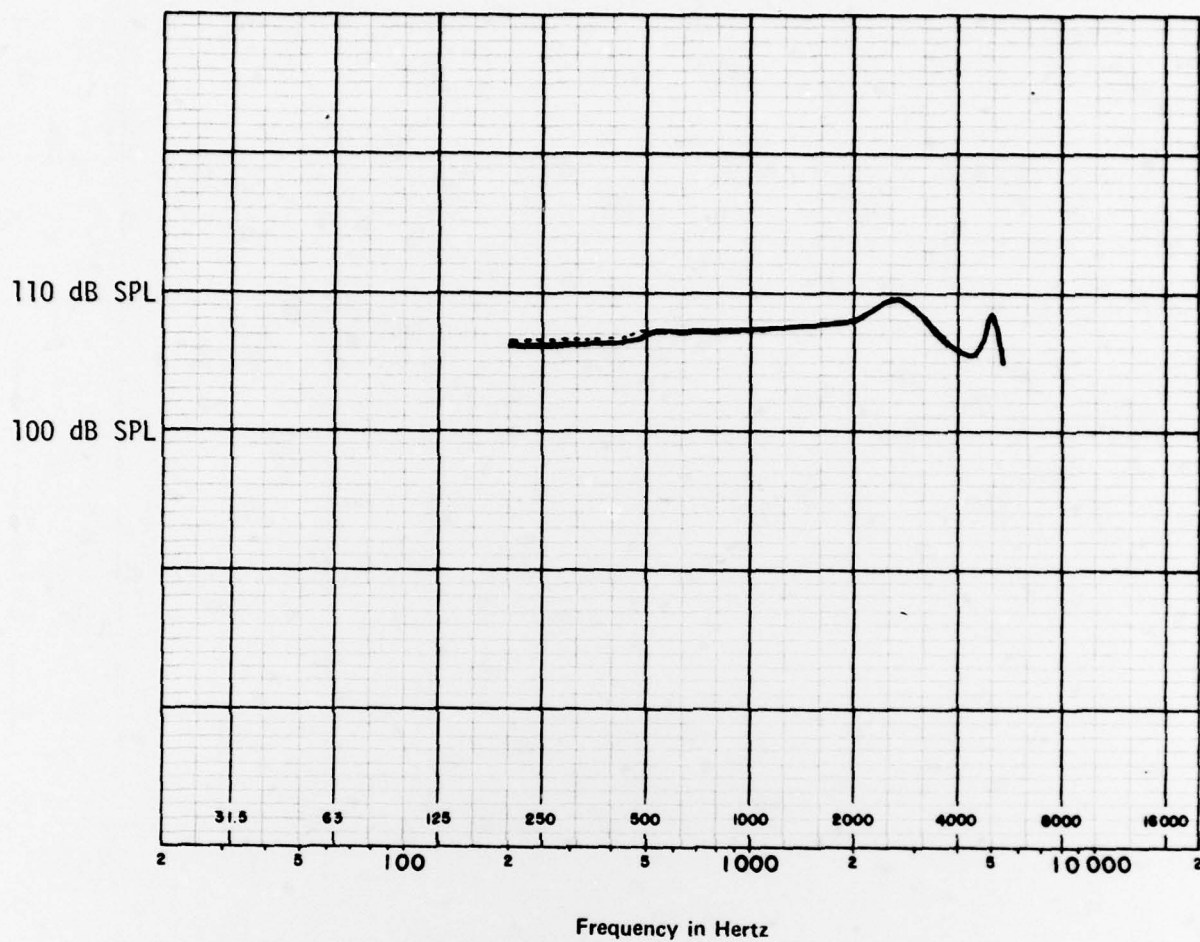
SUMMARY

A new earphone-earcup combination has been developed that will directly replace the earcup system now used in the DH-132 helmet which has improved intelligibility and reduced medical hazard to hearing for crewmen in tracked armored vehicles. This new design can be produced without adding weight to the helmet and does not sacrifice mechanical ruggedness for the larger volume and thinner walls of the new earcup.

Physical constraints of size and weight, plus practical considerations of comfort and fit prevented the obtainment of all the goals of DS-AF-0265A(A). Within the restraints of this design approach we have been able to show that an improved communications helmet system for use in tracked armored vehicles can be produced.

APPENDIX A

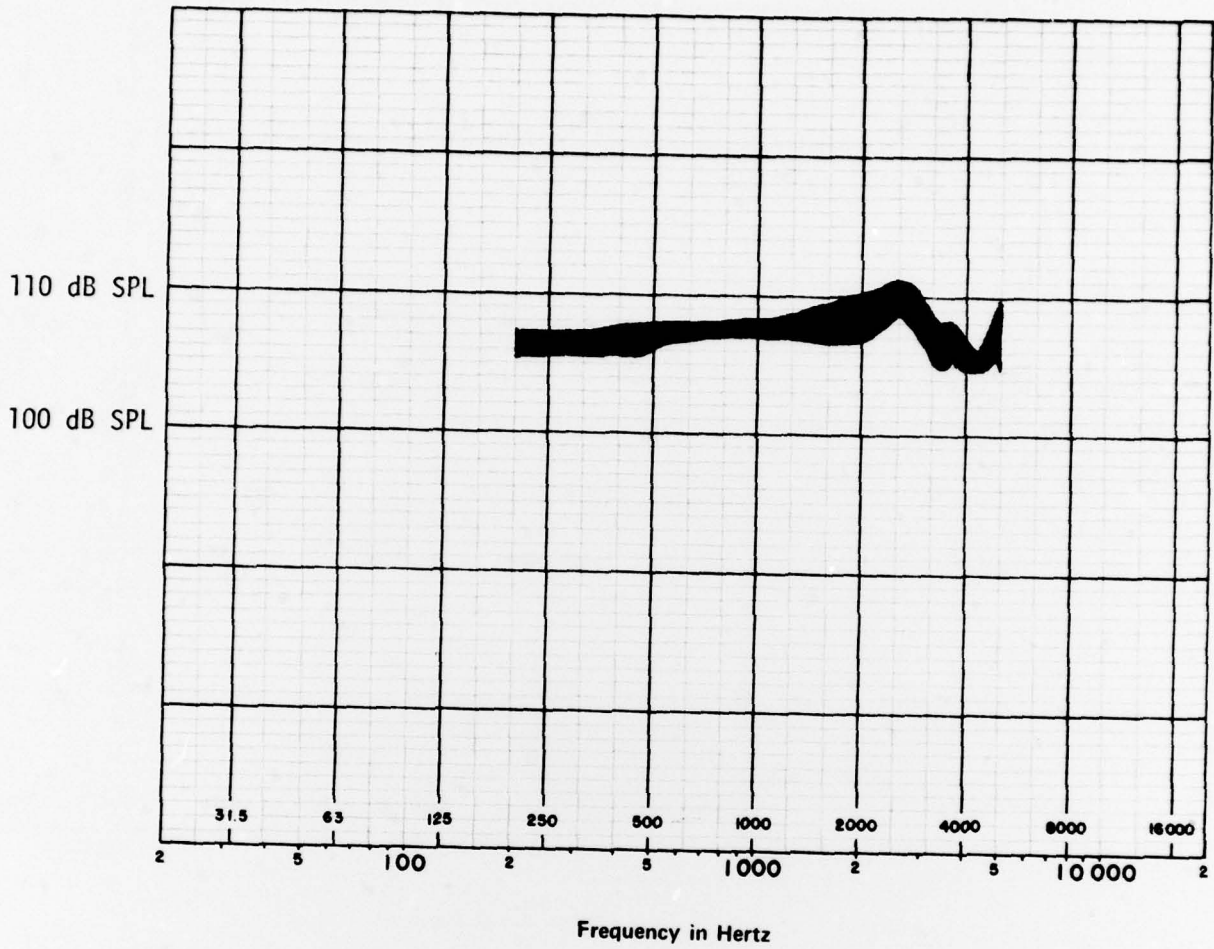
SAMPLE TEST DATA



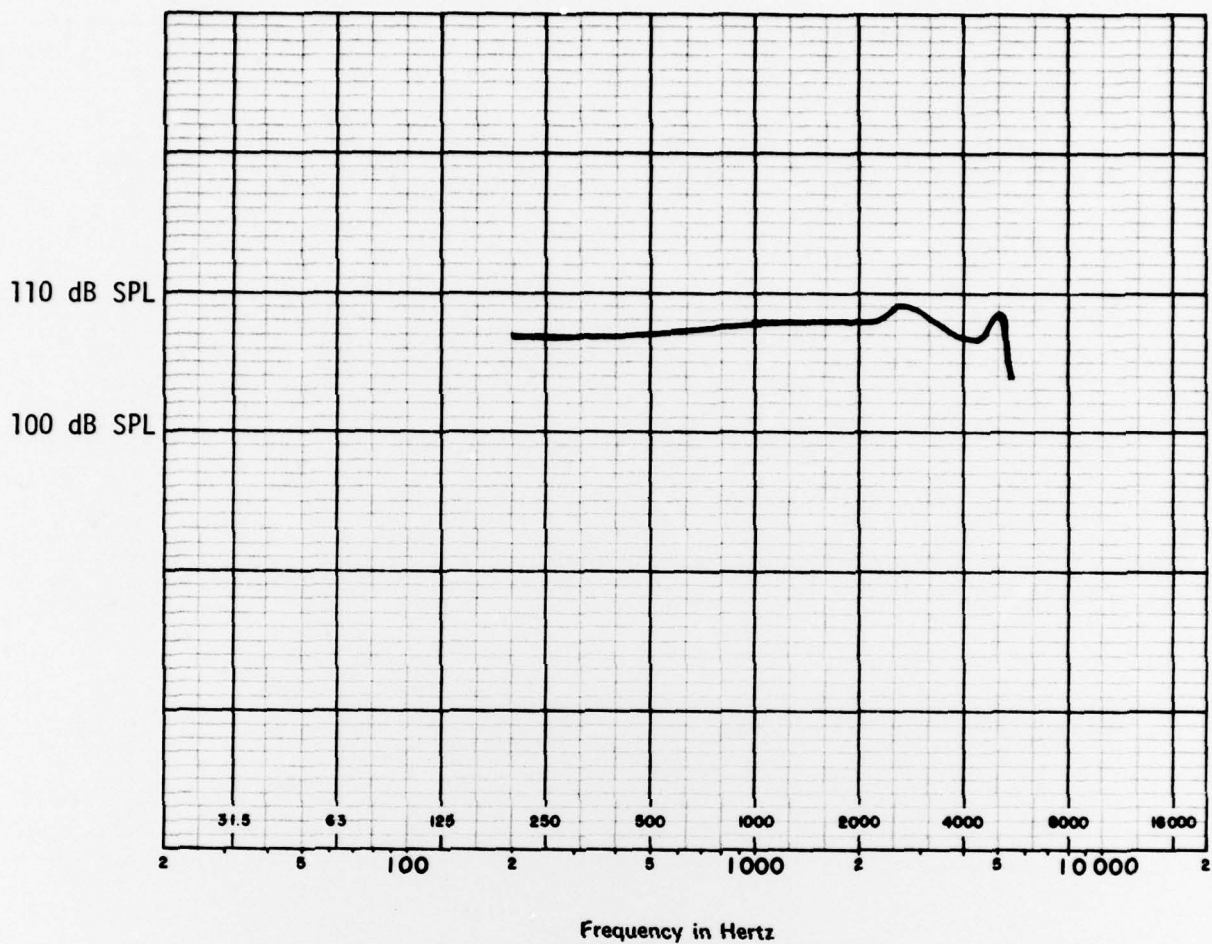
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----- After Overload Test

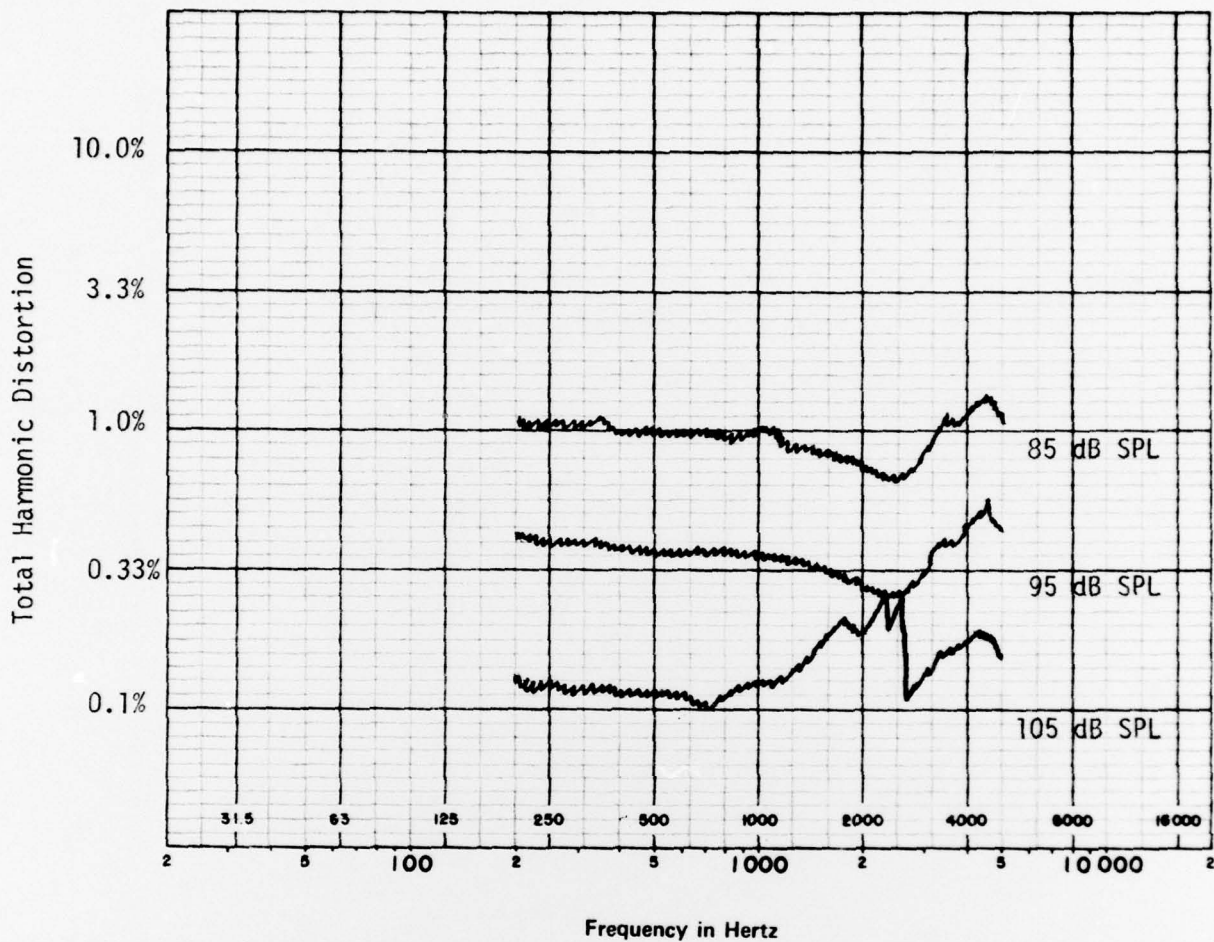


Frequency Response Spread of All Units Tested



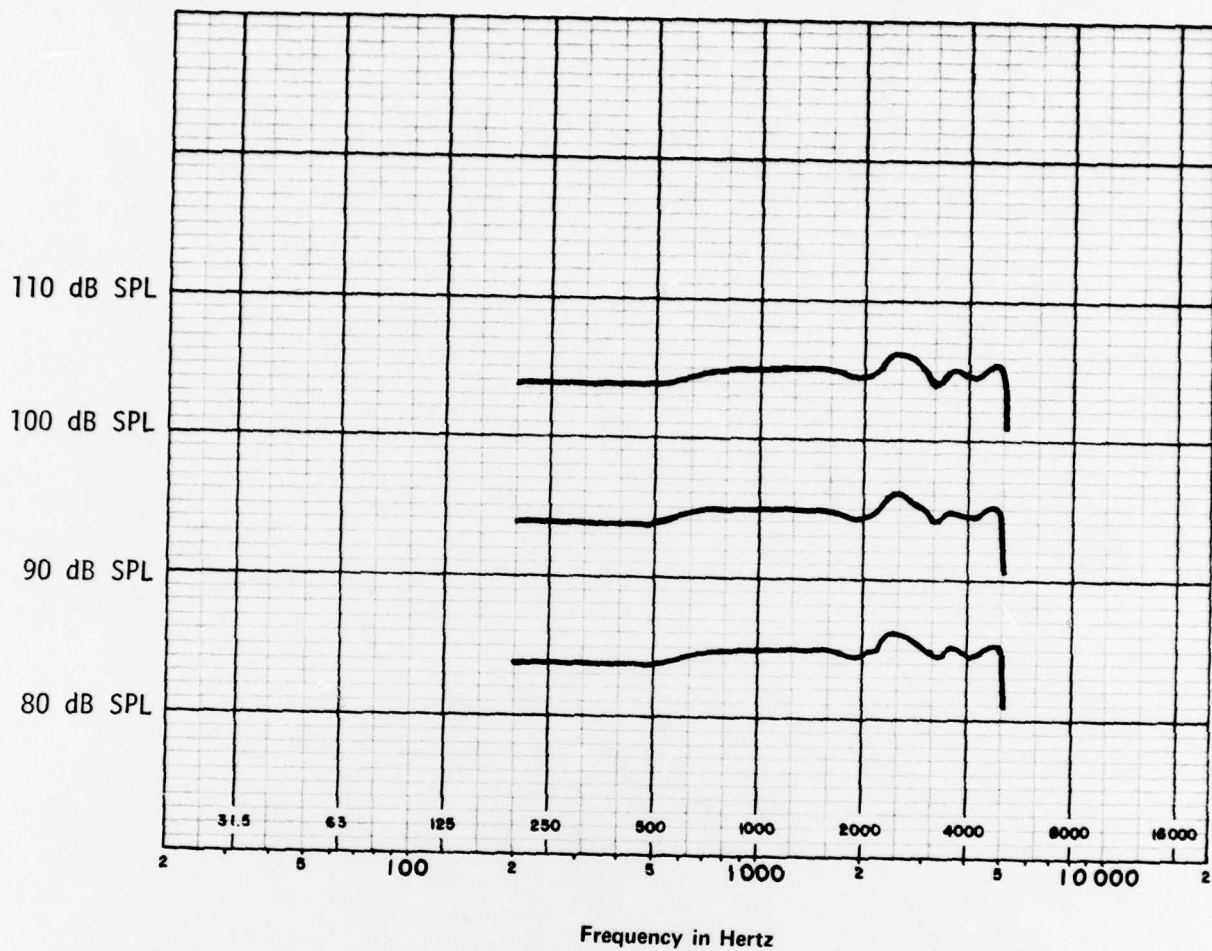
UNIT #6

Frequency Response



UNIT #1

Harmonic Distortion



UNIT #8

Linearity

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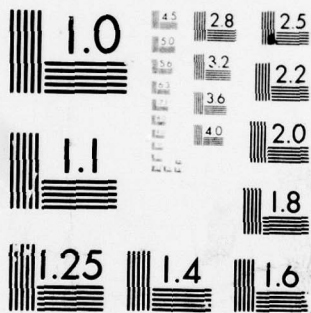
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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
CORADCOM-78-0176-F

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DEVELOPMENT OF IMPROVED EARPHONE-EARCUP SYSTEM
FOR AVC HELMET

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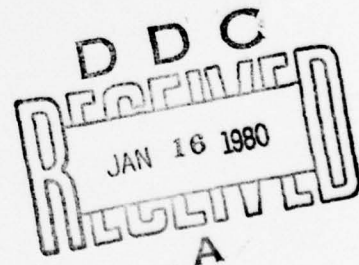
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OBJECTIVE

The objective of the technical effort described herein was a two-fold development project to improve the noise-attenuating and intelligibility properties of the earphone-earcup system used in the DH-132 Armored Vehicle Crewman Helmet.

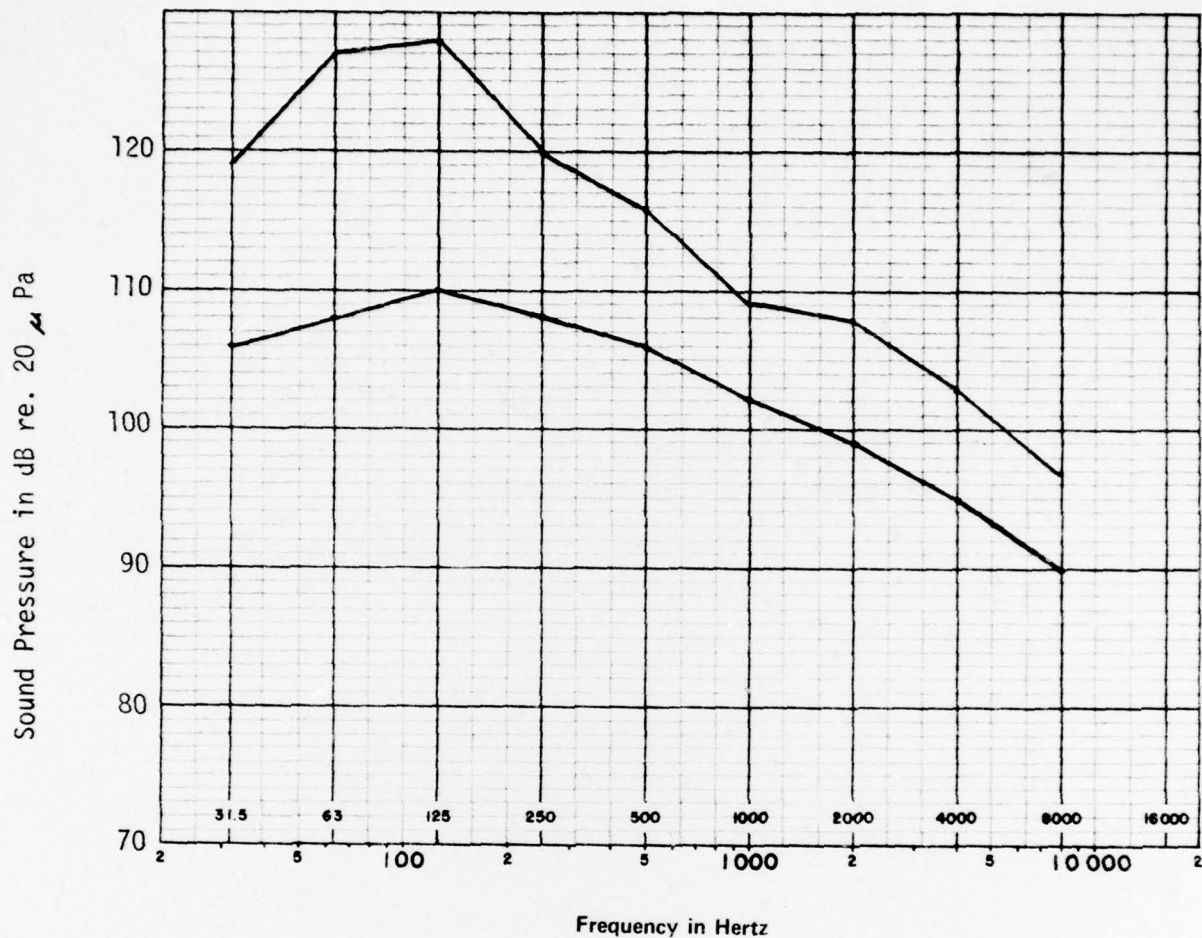
Problems with DH-132 Helmet

High sound pressure levels of noise are generated within tracked armored vehicles which necessitates the use of hearing protection for all crewman in the vehicle. When used in the prototype Mechanized Infantry Combat Vehicle (MICV) the noise attenuation characteristics of the DH-132 Helmet permit only one hour of exposure to the noise to comply with the requirements of U.S. Army publication TB MED 251.¹

The Electro-Voice Model 993 earphone element which was designed to operate against the ear, approximately a 6cc cavity volume, has a very non-linear frequency response when operated in the large cavity volume of the DH-132 earcup.

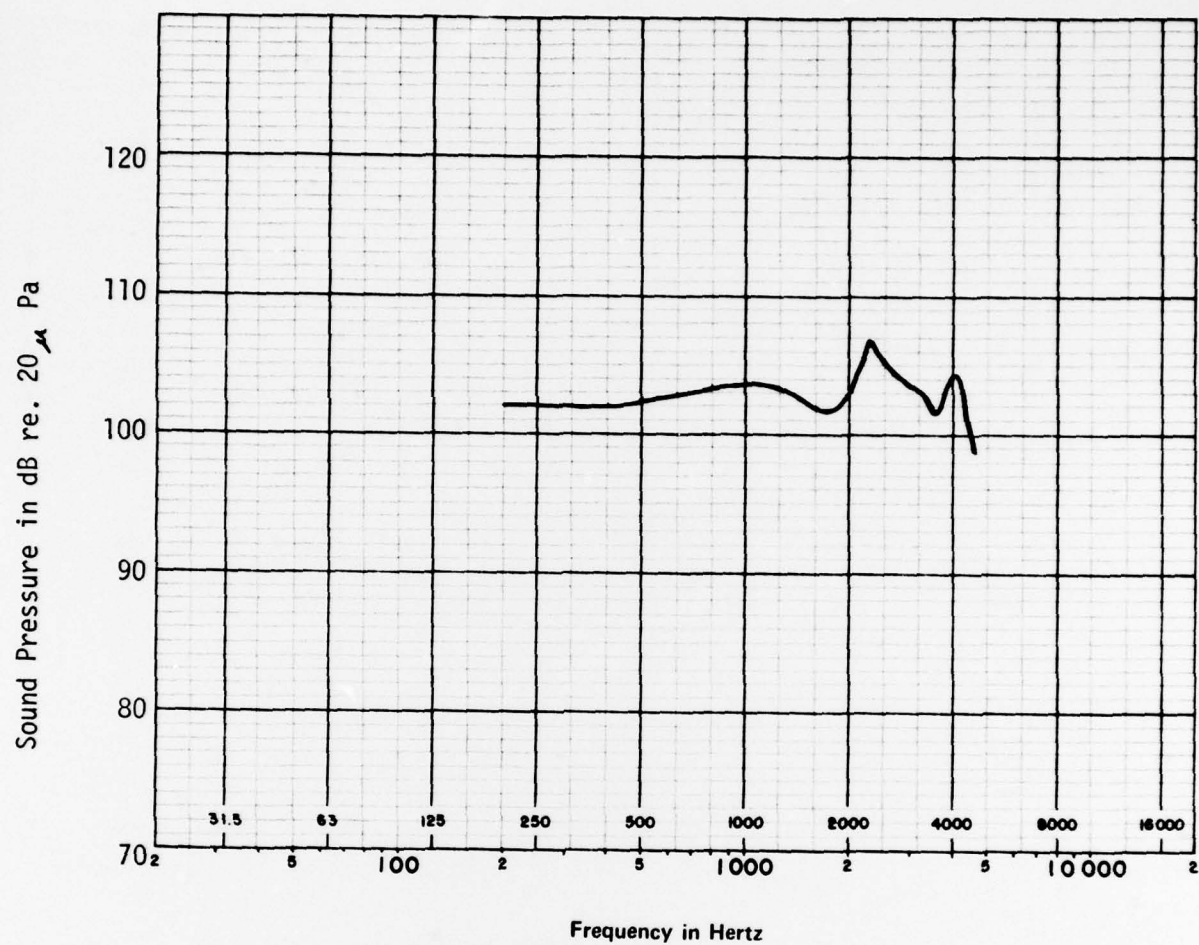
The seriousness of these problems is shown in Figures 1, 2, and 3 which show the sound levels generated within the MICV, and frequency response of the Model 993 when operated into a 6cc coupler and when operated in the DH-132 earcup.

¹USAARL REPORT NO. 77-8, Medical Assessment of Acoustic Protective Devices Proposed for Use in a Prototype Mechanized Infantry Combat Vehicle.



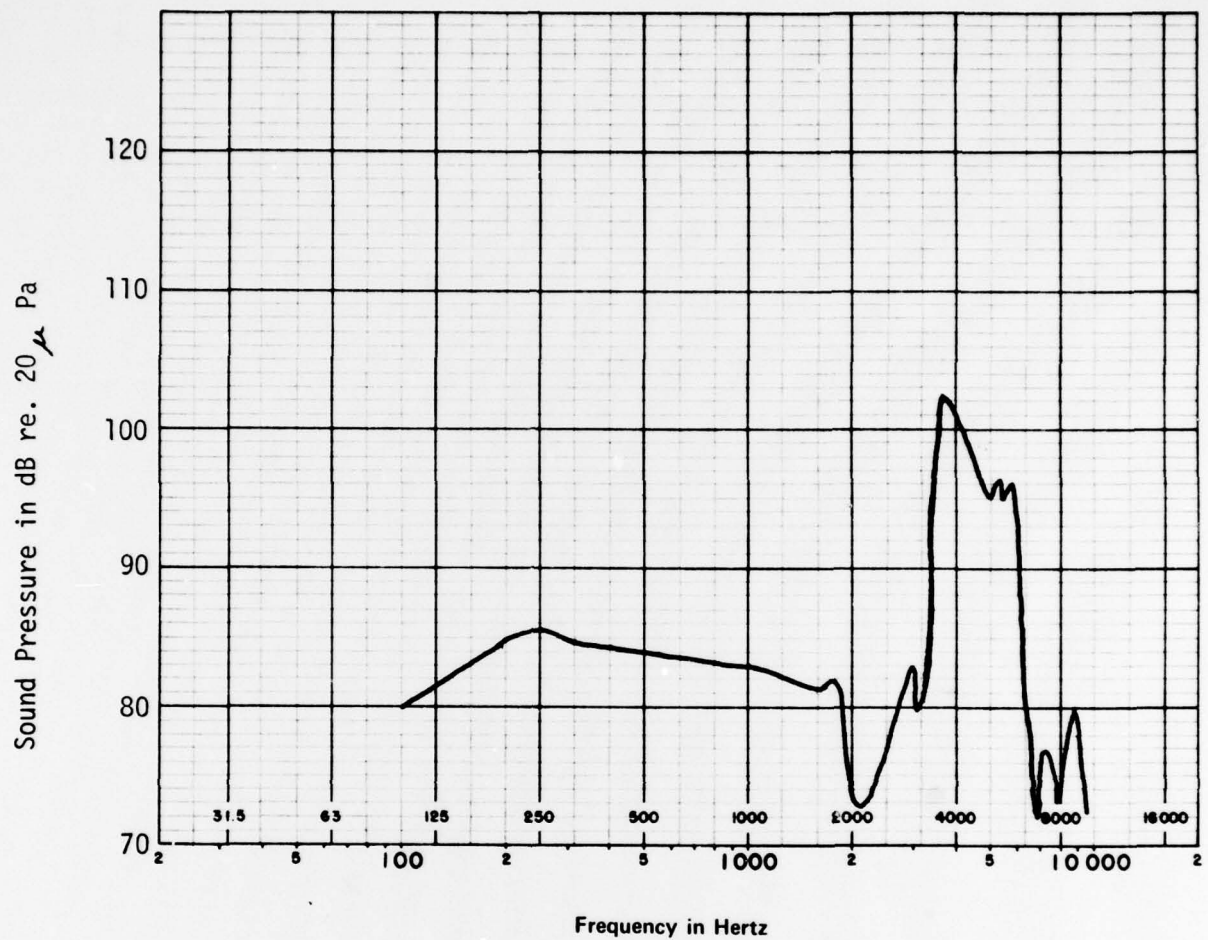
ENVELOPE OF NOISE SOUND PRESSURE LEVELS
FOR PROTOTYPE COMBAT TRACKED VEHICLE

Figure 1



MODEL 993 EARPHONE RESPONSE
ON 6cc COUPLER, 1 mW APPLIED

Figure 2



MODEL 993 EARPHONE IN DH-132 EARCUP,
1 mW APPLIED

Figure 3

Goals of Development Effort

One of the goals of this effort was to improve the noise attenuation of the earcup to allow eight hours of continuous exposure to noise encountered in the MICV and other tracked armored vehicles. The other goal was to generate a linear frequency response from the earphone when operated in the new earcup. This report demonstrates how these goals were attained.

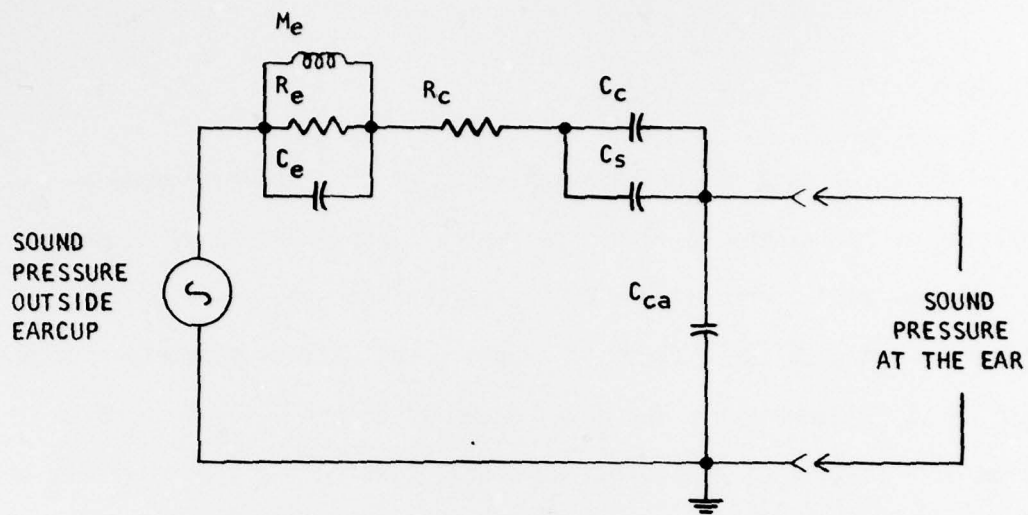
SYSTEM DESIGN

THE EARCUP

In order to understand the noise-attenuation of the earcup we used a simulation of the system to find areas where improvement could be made. An electrical equivalent circuit of the earcup was used along with a computer to evaluate the effects of changing the various parameters of the earcup on its attenuation. The model shown in Figure 4 is an improved version of a model used on a previous contract which has been modified to include the effects of the stiffness of the earcup. Changes to the earcup system are subject to the following conditions, however:

1. Weight of the earcup shall not be more than the existing DH-132 earcup.
2. A means to retain the earphone element shall be incorporated.
3. The earcup shall be physically interchangeable with the existing DH-132 earcup.
4. The earcup shall be constructed of an insulating material.
5. Earcups shall use the same switch and boom mounting hardware as the existing DH-132 earcups.

Analysis of the noise of the MICV shows that attenuation of the low frequencies is the most important area of improvement required. It was determined that the earcup volume could be increased approximately 25% and still meet the above restrictions. The improvement in attenuation by the larger earcup volume fell short of the DS-AF-0265A(A) design



M_e = Mass of total earcup system

R_e = Damping of earcup plastic material

C_e = Compliance of earcup

R_c = Damping of earcushion (Ignores damping of skin as earcushion value is much larger)

C_c = Compliance of earcushion

C_s = Compliance of skin

C_{ca} = Compliance of earcup cavity

ELECTRICAL CIRCUIT SIMULATION OF EARCUP SYSTEM

Figure (4)

requirements. Working with the computer simulation and experimenting with various materials, it was determined that a new earcushion filler material could provide the greatest improvement in low frequency noise attenuation.

Examining the circuit in Figure 4, we see that reducing the series compliance represented by the earcushion and the skin on the wearer's head decreases the signal presented to the ear via the cavity of the earcup at low frequencies. Using the computer simulation and tests on our dummy head, we have determined that the compliance of the skin limits the maximum attenuation of the earcup, with mass and volume fixed by restrictions above, between 30 and 35 dB, assuming a perfect seal and an earcushion with no compliance. Because of the differences in wearer's heads and comfort when wearing the helmet, an earcushion with some compliance must be used.

To meet the earcushion compliance requirements a new earcushion filler was needed. We tried a foam material called "Low-Perm" foam which has improved characteristics over the present filler; yet, this material is only produced in one compliance and has a closed cell construction. Another material called "Temper Foam" was found that is made in an open cell construction which is produced in five different compliances. Temper Foam is sensitive to both pressure and temperature along with a slow recovery rate property. A compliance that provides good comfort and low frequency attenuation is obtainable with this material. The compliance is highly temperature dependent, becoming very stiff at low temperatures. In actual use the wearer would warm the cushion with their hands and, when placed on the head, the warmth from the body would keep the cushion soft for comfort.

We are not able to obtain all the minimum attenuation values required by the specification, even with the increased volume and new cushion filler (see Table I and Figure 5). We feel the attenuation obtained at low frequencies is close to the highest practical value for this type of earcup design. A stiffer earcushion is available in Temper Foam, yet it will be uncomfortable and would require excess pressure against the head to obtain a seal.

Additional Earcup Design Details

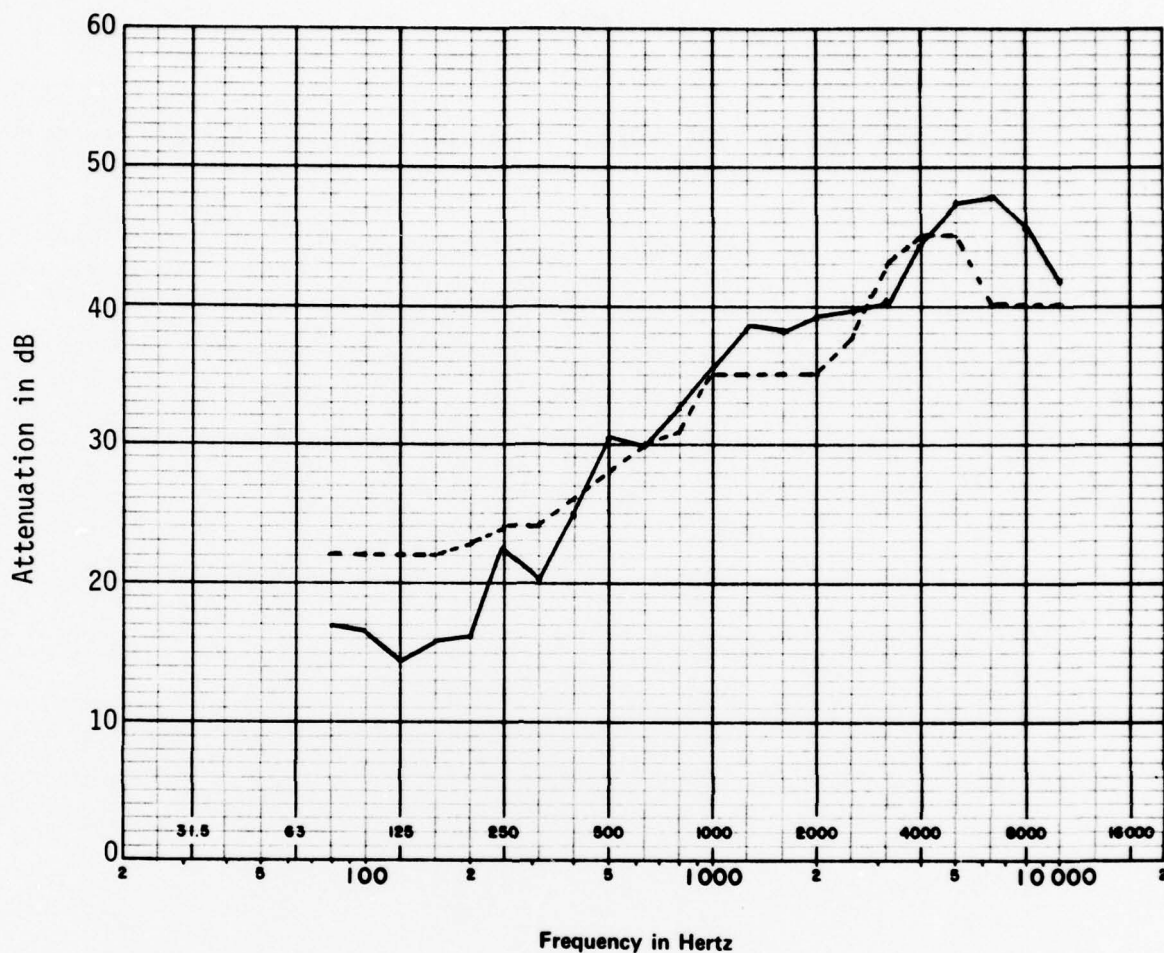
In order to increase the volume and keep the mass of the earcup the same, requires changes in the design of the earcup shape and material. The wall thickness had to be decreased which makes the earcup construction less stiff, reducing high frequency attenuation. In order to reduce the weight additionally and retain the stiffness of the thick ABS wall in the thinner wall, we used a nylon foam plastic material. When properly foamed and assembled, a nylon and nylon-foam earcup will be the same weight as the existing design and more rugged than the ABS design now used. Our prototypes used an ABS and nylon-foam construction because we would have to make four injection molds to produce the parts, where only two of the parts are of a new design configuration. Weight of the prototypes was higher than that which will be realized in the production models of the new design; however, the performance should be the same or better for the lighter versions.

For the earcushion cover we used a polyether polyurethane film. This film has been found to have superior properties when compared to the

TABLE I

Mean Attenuation of Twenty (20) Helmets Produced on Contract DAAB07-78-C-0176

1/3 Octave Band in Hertz	SPL of Noise Used for Test	Specification (Minimum)	Attenuation in dB	
			Mean	Deviation
80	93	22	16.9	3.3
100	102	22	16.4	3.6
125	107	22	14.5	3.8
160	105	22	15.7	3.6
200	102	23	16.1	3.7
250	108	24	22.4	2.8
315	108	24	20.3	1.8
400	105	26	24.8	2.0
500	103	28	30.4	2.3
630	101	30	29.9	3.3
800	99	31	32.7	2.4
1000	99	34	35.4	1.5
1250	99	34	38.4	1.8
1600	98	34	38.0	2.7
2000	98	34	39.1	2.0
2500	95	38	39.6	2.3
3150	95	43	40.3	5.5
4000	91	45	44.2	2.1
5000	90	45	47.5	2.6
6300	88	40	47.8	3.6
8000	86	40	45.8	2.6
10000	79	40	41.9	1.8



MEAN ATTENUATION OF 20 HELMETS
(SEE TABLE I)

----- Specification (Minimum)
——— Mean

Figure 5

vinyl film used presently. We tested this film on a previous development contract (DAAB07-76-C-0149) in which it was shown to be flexible at sub-zero temperatures, fungus resistant and tear resistant.

THE EARPHONE

As explained in the beginning of this report, the Model 993 and other earphones which are designed to operate into a 6cc cavity do not perform well in a large earcup. Two possible design modifications are:

1. Mount the earphone to closely couple it to the ear as it was designed to operate.
2. Redesign the earphone to operate in the large earcup.

From past experience we decided to concentrate our efforts on placing the earphone against the ear. To make a lightweight earphone element operate in a large earcup, we would have to sacrifice efficiency and frequency response which is undesirable.

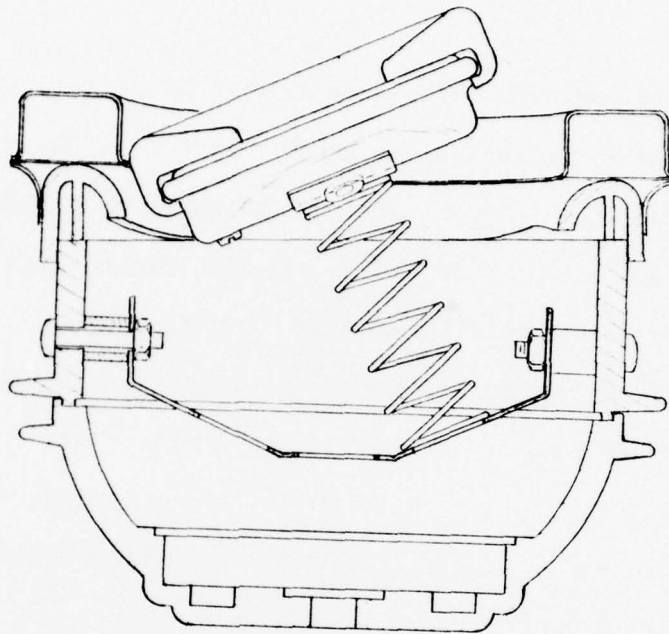
Positioning and sealing the earphone against the ear are the most difficult problems caused by the closely coupled design approach. Variations in user ear dimensions necessitate a loose attachment of the earphone to the earcup. The positioning mechanism must be lightweight, exert a small force to hold the earphone in the proper position, and allow easy placement and removal of the helmet. An additional requirement is to make the earphone a replaceable item separate from the earcup. Since the earphone cover presents a hard, flat surface to the ear, some form of cushion between the ear and earphone is required to provide a good seal and comfort to the wearer.

Design of Closely Coupled Assembly

Figure 6 shows the method chosen to support the earphone in the earcup. A compression spring is attached to the earphone element and a mounting bracket. We chose to permanently attach the spring assembly to the earphone as this provided the lightest weight construction and only required minor modifications to the earphone case. For the prototypes the spring was soldered to metal brackets at each end--an assembly method that would not be used on a production version. The reliability of the soldered connection has been found to be poor even though the unit used in the drop test held together. Production units should incorporate some sort of metal tabs from the brackets which could be crimped over the spring and lock it in place.

A force of $1/3$ to $1/2$ kilogram was chosen to be applied by the spring when pressing against the ear. Most earcups are designed with a one kilogram force. If we used one kilogram of force for this application, then the earcup would have to apply two kilograms force against the head, which is excessive! The spring force was selected as a reasonable compromise for the total force applied to the wearer's head.

Various materials and earpad shapes for sealing the earphone to the ear were tested. A lightweight ring fashioned out of polyurethane foam was evaluated. The foam provided a good seal but has two drawbacks. Because of its compliance it allows the earphone to move in relationship to the head and thus lowers the noise attenuation of the earcup system. Also, the foam would be difficult to clean, presenting a hygiene problem. The selected material is a soft, rubber-like plastic that can be molded into

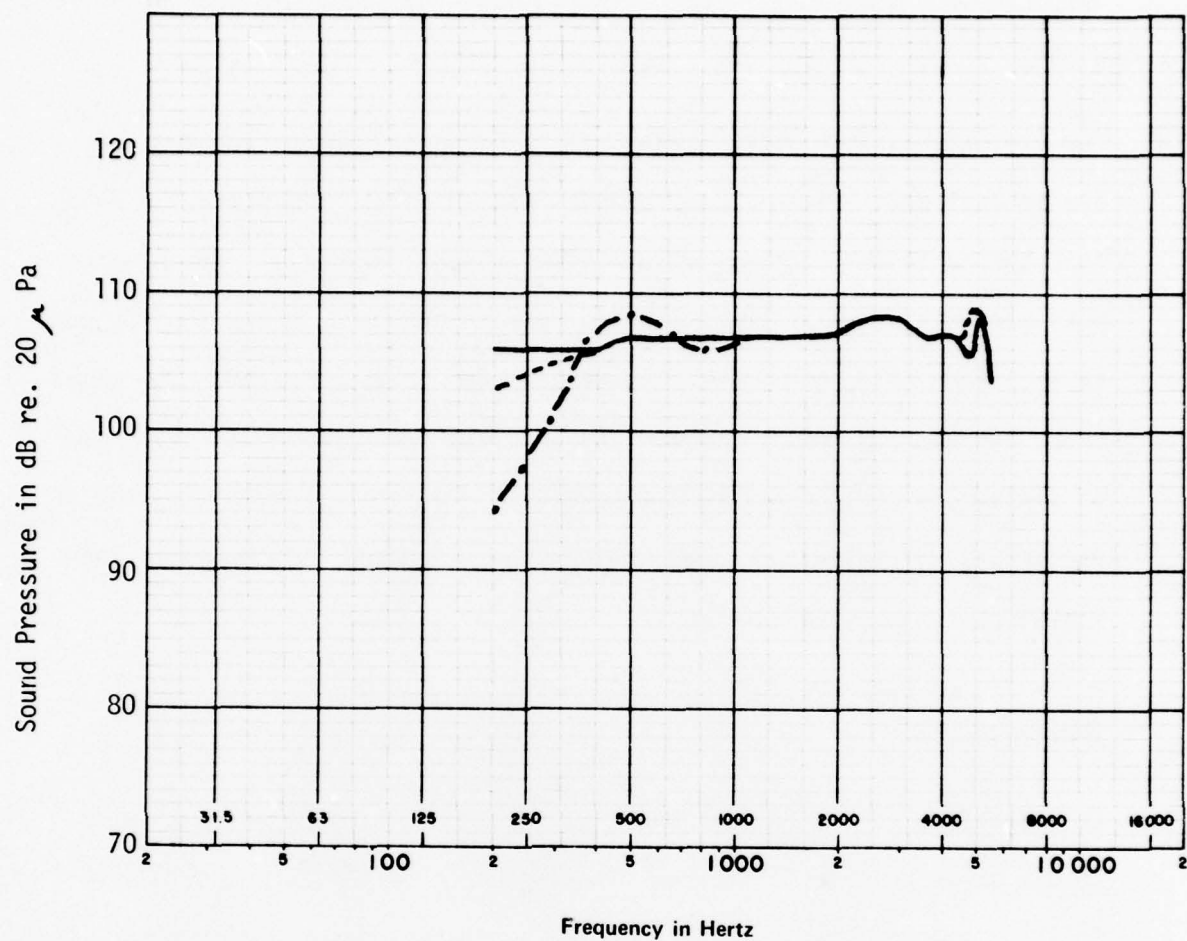


Cross Section of Earphone-Earcup System

Figure 6

the desired shape. This material, "Satinflex", has a compliance almost identical to human skin, is fungus resistant and is easy to clean. We have molded it as a replaceable earpad to be placed over the earphone element.

Since we had to compromise the force applied to the ear, the seal obtained is not adequate to obtain a response that is flat to 200 Hertz. When properly fitted, the frequency response measured at the ear consistently falls within a 6 dB envelope from 400 to 5000 Hertz. Figure 7 shows the variation in response obtained because of differences in sealing. The frequency response is better than we would expect to obtain from an earphone modified to work in the earcup and should provide good intelligibility. We feel the loss in low frequency response is acceptable as the added force for a good seal would be uncomfortable when the helmet is worn for extended periods.



VARIATIONS IN RESPONSE CAUSED BY CLAMPING PRESSURE

- 6cc Frequency Response
- 1 Kg Force
- 1/3 Kg Force

Figure 7

DESIGN TESTS

Weight

Our prototypes weigh approximately 25 grams more than the earcups they are to replace. Examining the density of the nylon foam parts, we found that the parts were not processed by the vendor correctly. In order to make good parts, water cooling would have to be added to the tooling and an injection molding machine with better control is required. The added delay and cost to modify the tooling and make new parts would only result in parts with reduced weight and have little affect on evaluating the performance of the earcup. We chose to go ahead and use the nylon foam plastic parts as received.

Impedance

The impedance of all the earphones was measured with the units mounted to the dummy head test fixture. The impedance of the earphones was 10 to 15 ohms lower than the value of the impedance measured when the earphones are unloaded. Because the impedance changes less than 2% from a loaded to unloaded condition, the measurement technique has little effect on the result. Measuring the impedance in free air is easier and yields the desired results.

Dielectric Strength, Insulation Resistance and Overload

These tests are common to all our earphone designs. We use materials and construction techniques that allow our earphones to consistently pass these tests. All the earphones made on this contract were subjected to and passed the above tests.

Sensitivity

With one milliwatt of power applied to the earphone, the output pressure was always above 104 dB SPL. The specification allowed a minimum level of 85 dB SPL for an earphone which would operate into the earcup. Since the closely coupled approach has been used, 104 dB SPL should be the new minimum level for one milliwatt input in this application.

Frequency Response

As explained in the section on the earphone, the frequency response measured at the ear is dependent on the pressure applied to provide a seal to the ear. When measured on a 6cc coupler or with sufficient pressure applied and measured at the ear, the response falls within a 6 dB envelope between 200 and 5000 Hertz. The high mass of a practical 1000 ohm voice coil limits the response to a 5000 Hertz maximum. It might be possible to use smaller wire in the voice coil to extend the response to 6000 Hertz as the specification calls for, but past experience shows the resulting unit is difficult to build, would be less reliable, and might have difficulty passing an overload test.

Because of the variations in microphone placement and human ear dimensions, we recommend that the 6cc coupler be the standard for testing the earphone with the limits between 200 and 5000 Hertz rather than the in ear technique which is not standardized.

Harmonic Distortion

Measuring the distortion per the design specification presented a problem. Our earphones, when operated into a 6cc coupler and against the ear 'typically', have less than 1% distortion. We placed the dummy head in our large anechoic chamber, which is the quietest room we have, where the ambient noise level is on the order of 45 dB SPL. The noise level in the chamber looks like 1% harmonic distortion at the measurement level of 85 dB SPL. Only the 105 dB SPL measurement level gave us a signal to noise level sufficient to measure harmonic distortion.

Because of the low distortion levels and expense of testing, only the 105 dB SPL measurement level should be used as a specification requirement for harmonic distortion of the earphone.

Linearity

A constant voltage versus frequency at three voltage levels was applied to the earphones. The output sound pressure was recorded for the three input levels. The output sound level varied linearly with the input voltage level.

Attenuation

Various ways of measuring the noise attenuation of the earcup system were used for evaluation. The values obtained in Table I were measured on a dummy head with a noise spectrum that simulated that of a tracked armored vehicle. These values are not as good as expected, but are representative of those to be realized in actual usage. When a flat sound spectrum at lower sound pressure levels is used instead of the shaped spectrum, the values of attenuation are greater and correlate better with our computer simulation. We do not report the latter attenuation values as they apply to a test method which is not representative of actual use. Tests were made with a miniature microphone placed in a subject's ear to further verify the attenuation values of the dummy head test fixture. Because of electrical signal to noise, the attenuation at high frequencies could not be measured accurately. This is because the sensitivity of the miniature microphone is much lower than the one inch B & K microphone used in the dummy head. The values in the low to middle frequencies agreed with that recorded with the dummy head. More theoretical study is needed to determine why the attenuation at high sound levels decreases when compared to moderately high sound levels.

ENVIRONMENTAL TESTS

Low Temperature

An earphone-earcup system was exposed to -50° C temperature as specified in DS-AF-0265A(A). After the temperature of the unit had stabilized, a signal was applied and the level recorded. At the low temperature the level increased 2 dB. When returned to ambient temperature, the level and response were identical to that taken before the test.

High Temperature

No change in performance of the earphone-earcup system was experienced as a result of exposure to 160° F temperature. When checked at 160° F the level had decreased one dB from the level at ambient temperature.

Rain

The rain test trapped more water in the front cover than expected. Only a slight shake was used to remove the water before testing the unit's response. Minor degradation was noted immediately after the rain test. Later, when the rest of the water trapped had been removed, the unit showed no degradation.

Immersion

Immersion tests were run twice on the earphone-earcup system as required by the design specification. We recorded the frequency response before and after the test, and only minor differences were noted.

Dust, Fungus and Blast

These tests were not performed on this contract. The design and materials used in the earphone and earcup have been shown to be resistant to these tests, thus, we passed over these tests to concentrate on other tasks in the design.

Humidity

Examination of the unit after exposure showed no visible change. No degradation of the sensitivity was noted after the test.

Vibration

Exposure to the vibration test caused a minor change to the frequency response. The unit still met specification requirements as a result of the exposure.

Shock, Drop

Dropping a unit 26 times on to a two inch thick piece of plywood backed by concrete from a height of four feet caused no degradation to the unit's performance, even after immersing it in water as specified by DS-AF-0265A(A)

Salt Fog

One unit was exposed to the 48 hour salt fog test of MIL-STD-810C, Method 509.1, Procedure I. Only a slight discoloration on the spring assembly was observed with no degradation in the frequency response.

Altitude

The earphone-earcup system was subjected to an operating and non-operating altitude test. Because of the air tight seal of the earcup to the dummy head test fixture, the unit would not equalize rapidly at a 15,000 feet simulated altitude. When a small leak was provided in the earcushion seal, the unit equalized normally and the response changed only 3 dB at the high frequencies relative to the ground level response. In actual use this sealing characteristic should not present a problem. If data from the field shows this to be a problem, then an equalization port can be added. A non-operating altitude test of a simulated 40,000 feet altitude caused no degradation to the frequency response when the unit was tested afterward.

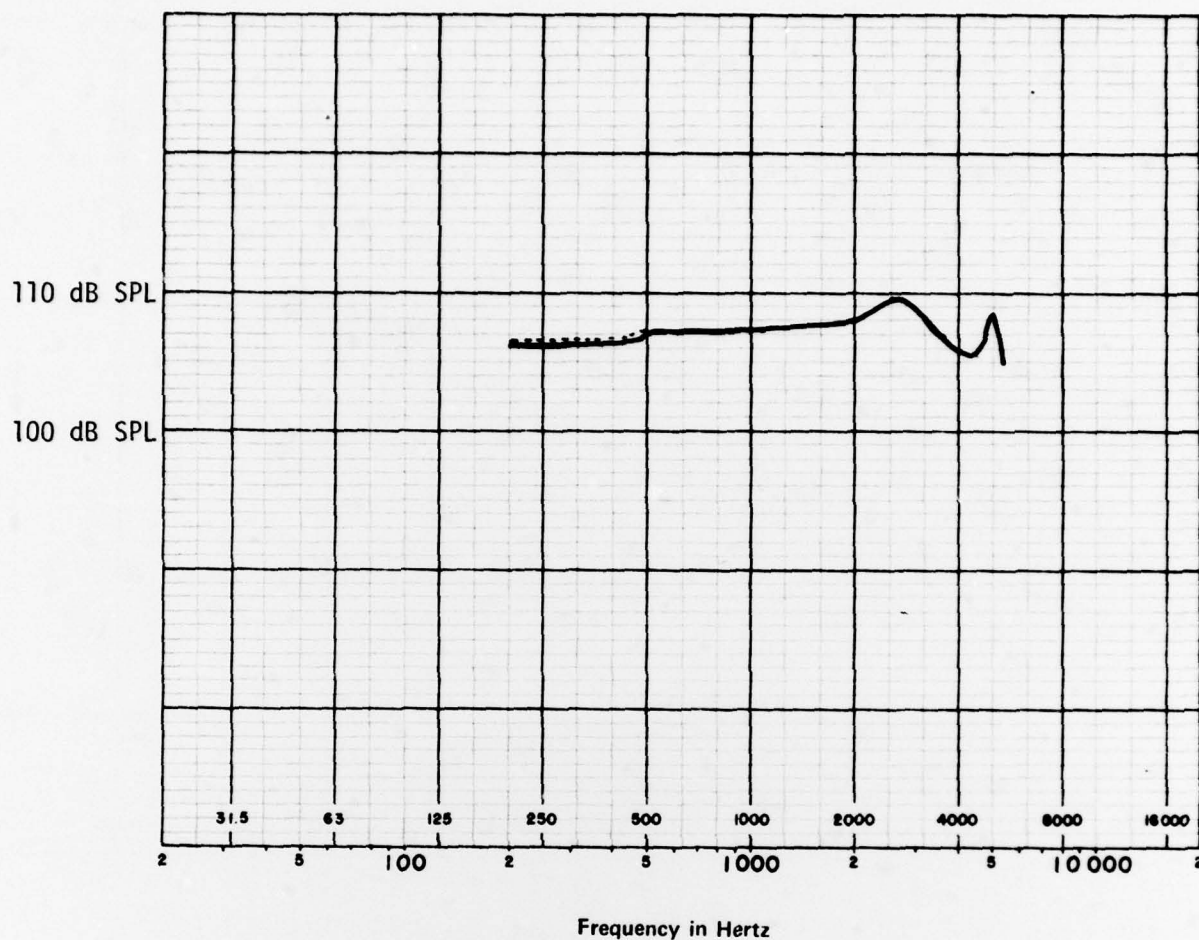
SUMMARY

A new earphone-earcup combination has been developed that will directly replace the earcup system now used in the DH-132 helmet which has improved intelligibility and reduced medical hazard to hearing for crewmen in tracked armored vehicles. This new design can be produced without adding weight to the helmet and does not sacrifice mechanical ruggedness for the larger volume and thinner walls of the new earcup.

Physical constraints of size and weight, plus practical considerations of comfort and fit prevented the obtainment of all the goals of DS-AF-0265A(A). Within the restraints of this design approach we have been able to show that an improved communications helmet system for use in tracked armored vehicles can be produced.

APPENDIX A

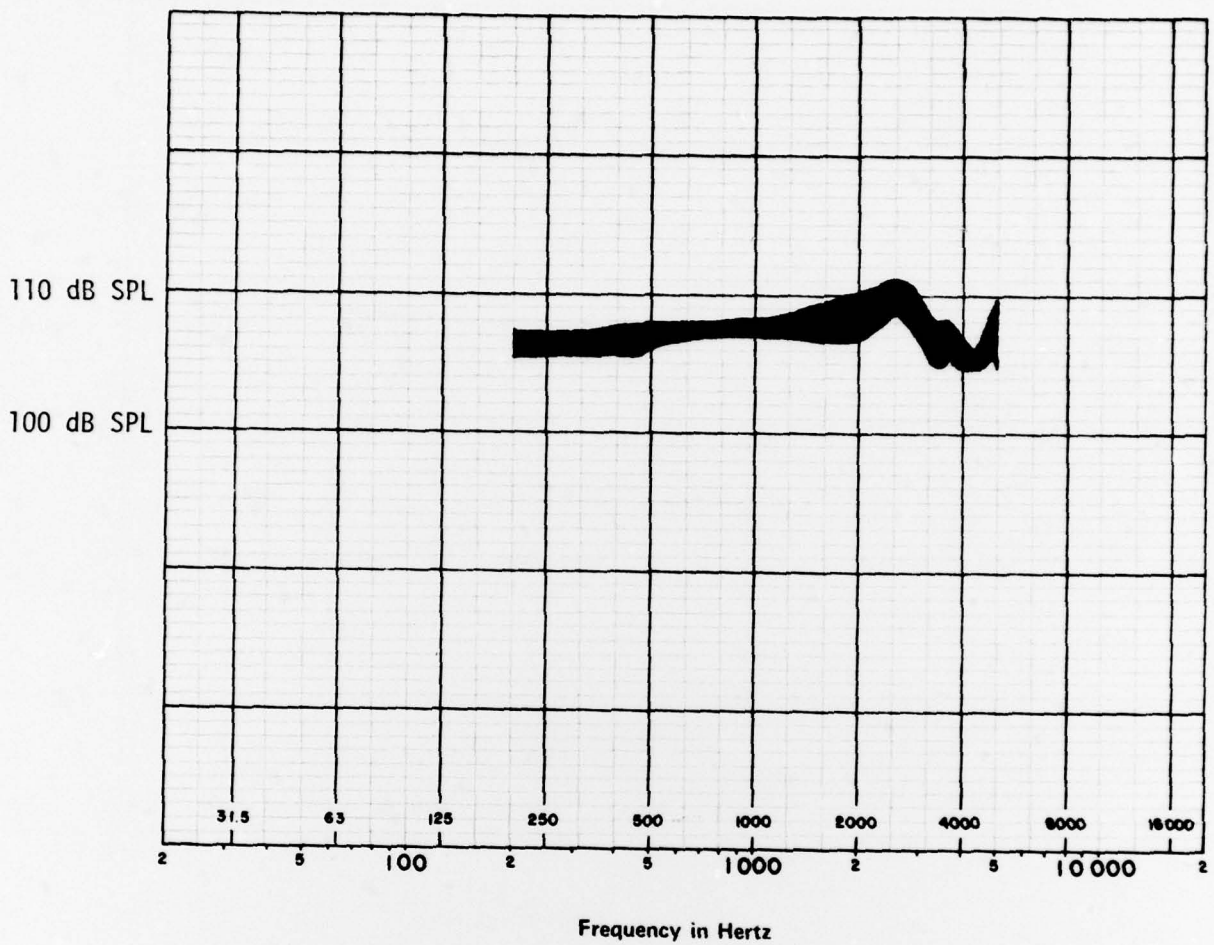
SAMPLE TEST DATA



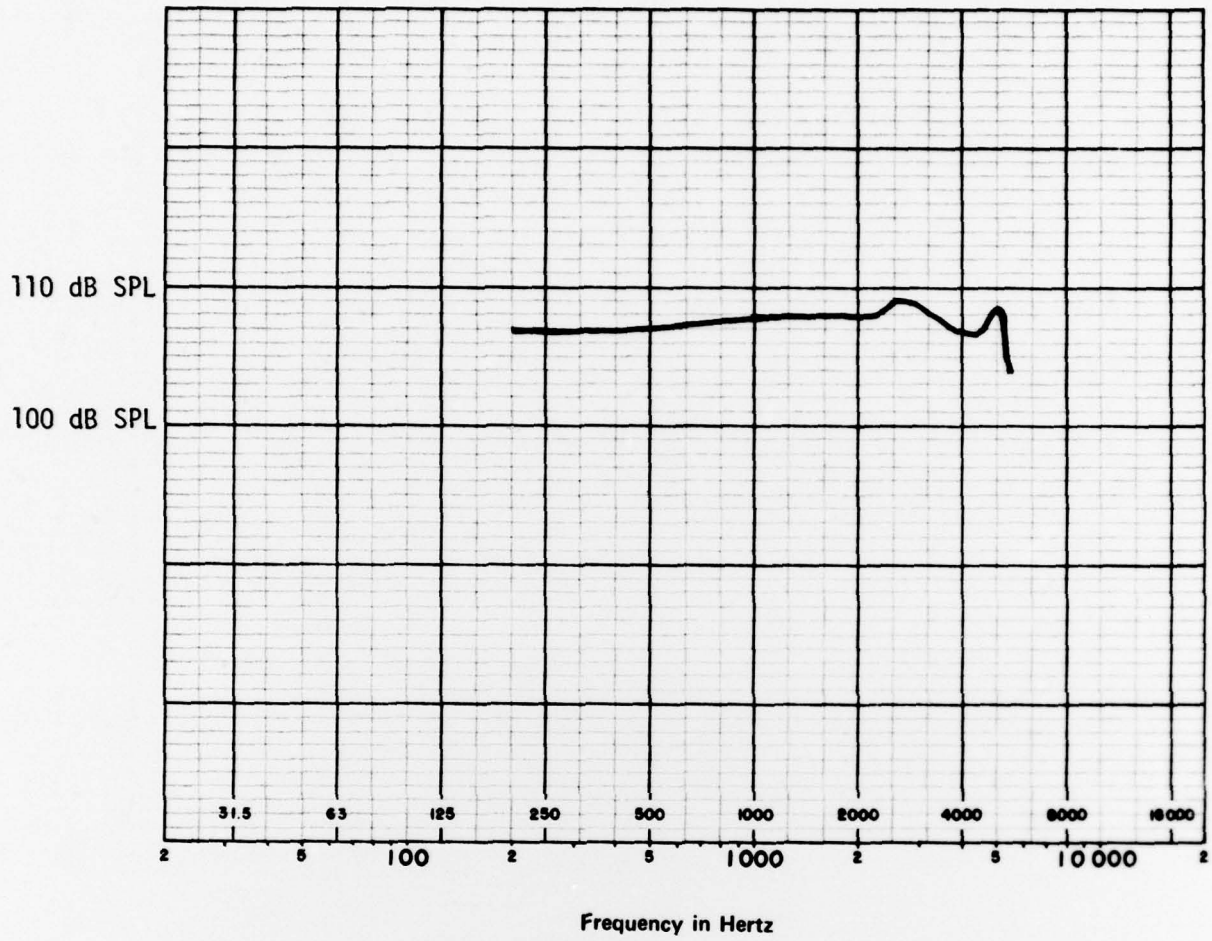
UNIT #3

_____ Before Overload Test

----- After Overload Test

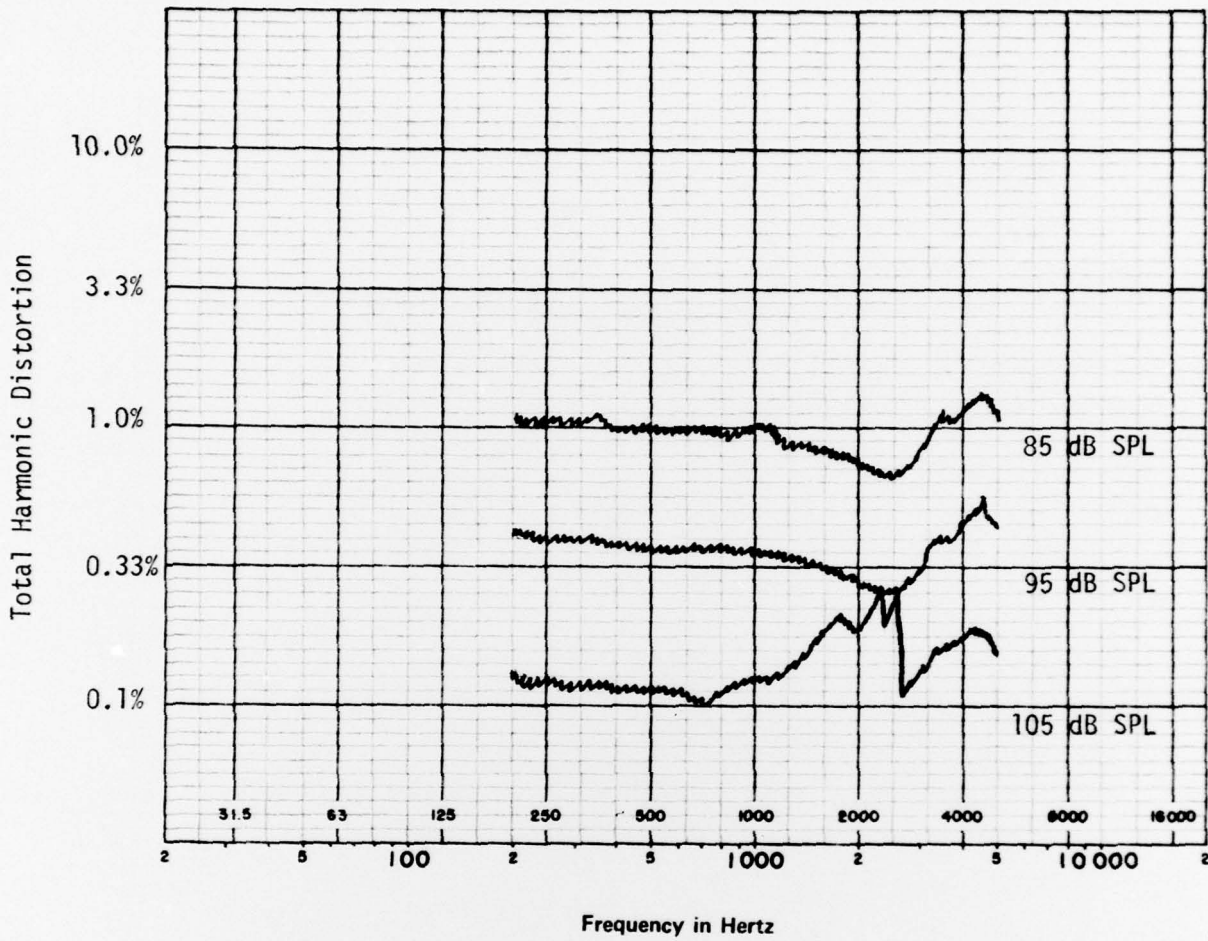


Frequency Response Spread of All Units Tested



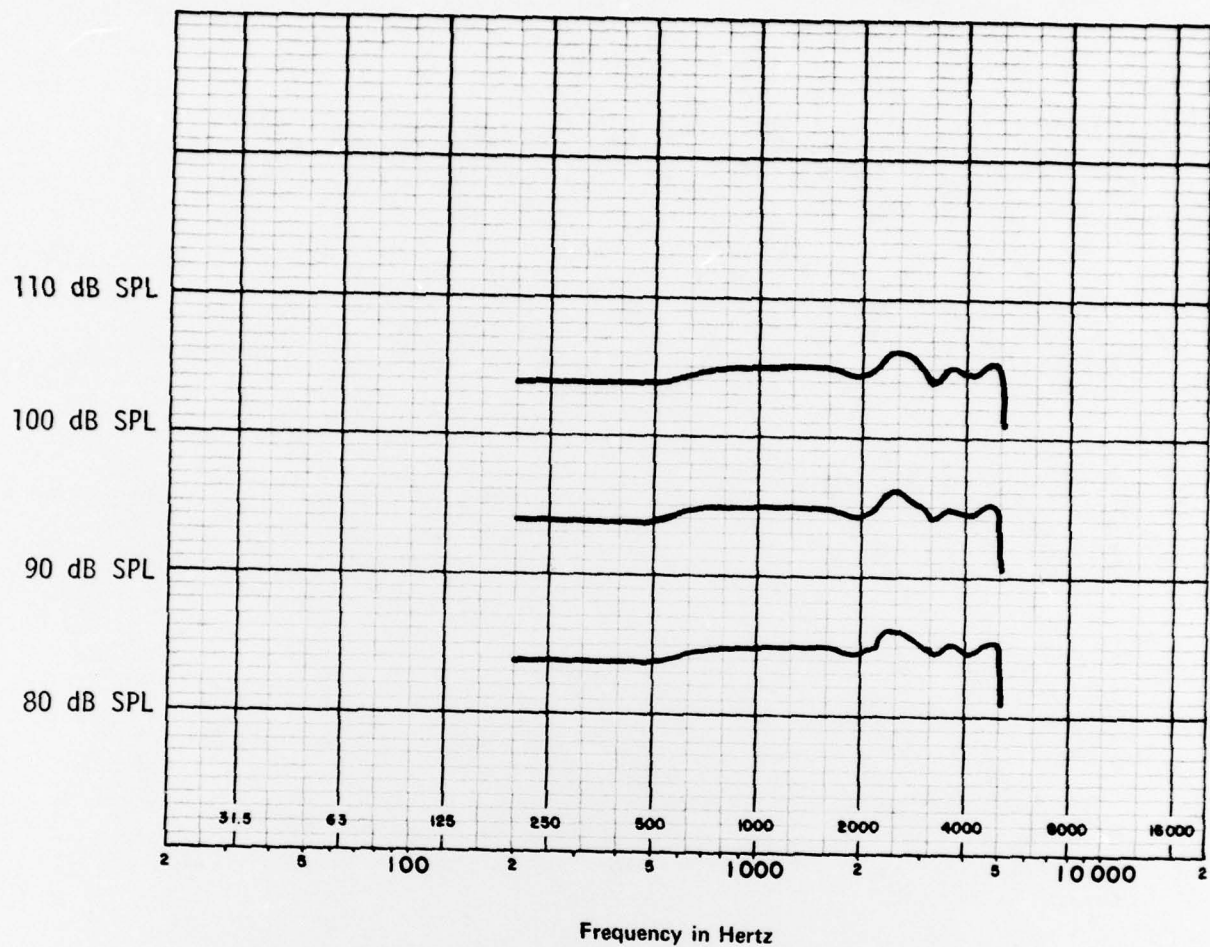
UNIT #6

Frequency Response



UNIT #1

Harmonic Distortion



UNIT #8

Linearity

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